R4138 1-AK-DP

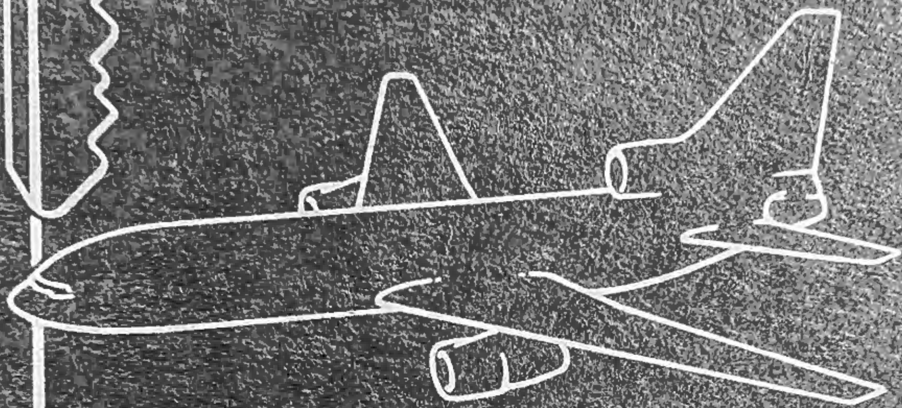
AUGUST 15, 1975

VOLUME 2

MASTER KEY

L1011 TRISTAR

AUXILIARY POWER UNIT



- SYSTEM DESCRIPTION/OPERATION
- TROUBLE SHOOTING

ST6L-73 ENGINE

LOAD COMPRESSOR SYSTEM

CONTROLS AND INDICATOR INTERFACES

APU CONTROL SYSTEM

APU COMPARTMENT INTERFACES

APU TROUBLE SHOOTING

HAMILTON STANDARD

UNITED TECHNOLOGIES

Mario Santana Jr.

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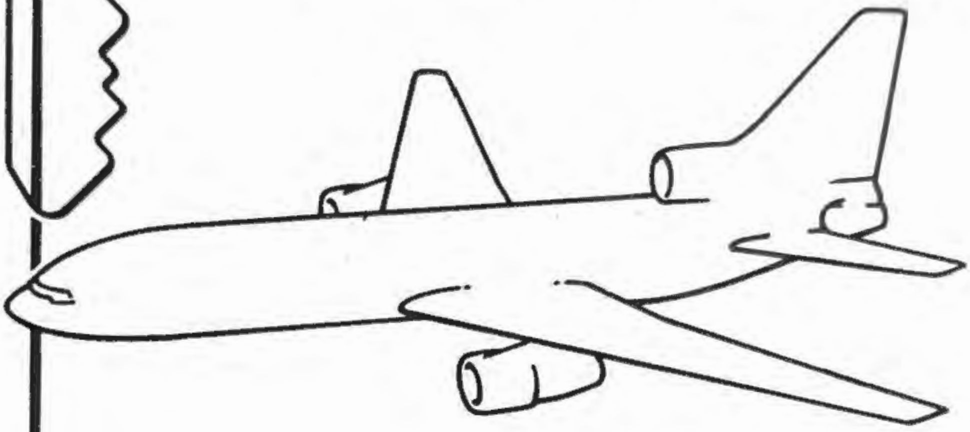


- SYSTEM DESCRIPTION / OPERATION
- TROUBLE SHOOTING

This document is intended to provide overall system orientation information and should not be construed as amending or superseding approved official maintenance, manuals, overhaul manuals or service bulletins nor should this information be construed as modifying in any way Hamilton Standard's applicable warranties or guarantees covering equipment described herein.

HAMILTON STANDARD Division of UNITED TECHNOLOGIES

The intent of this handbook is to provide information pertaining to the Auxiliary Power Unit (APU) and in particular those components which are supplied by Hamilton Standard Division of United Technologies Corporation. The ST6L-73 Engine and its accessories and the Load Compressor System and its components constitute the Auxiliary Power Unit. No attempt has been made to describe in detail vendor supplied components but this handbook does describe direct and indirect electrical and mechanical interfaces with those components where understanding of the system operation is affected.

<u>L1011 TRISTAR AUXILIARY POWER UNIT</u>

- INTRODUCTION
- ST6L-73 ENGINE
- LOAD COMPRESSOR SYSTEM
- CONTROLS AND INDICATOR INTERFACES
- APU CONTROL SYSTEM
- APU COMPARTMENT INTERFACES
- APU TROUBLESHOOTING

L1011 AUXILIARY POWER UNIT

INTRODUCTION

General

The L1011 Auxiliary Power Unit (APU) (Figure 1) provides a source of electrical and pneumatic supplies for aircraft systems. While the aircraft is on the ground, the APU is capable of satisfying aircraft electrical and pneumatic requirements without the need for any other power sources.

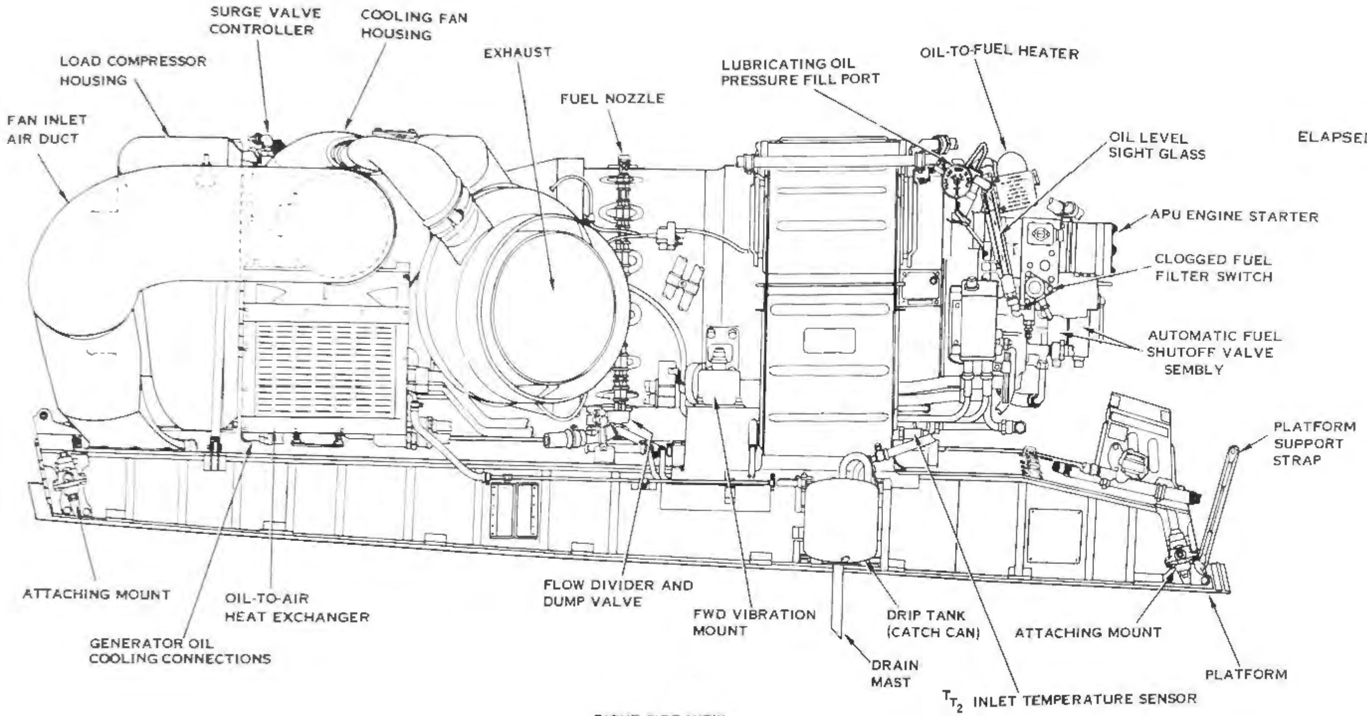
The L1011 Auxiliary Power Unit as a system consists of an APU Electronic Controller, an Auxiliary Power Unit, and an APU Exhaust Muffler. To satisfy the requirements of this handbook, the APU system is treated as follows:

- ST6L-73 Engine - Converts the energy from combustion into a rotational force driving a free turbine which drives the load compressor system.
- Load Compressor System - Provides constant frequency electrical power by driving an ac generator, provides APU engine air cooling through a cooling fan, and supplies compressed air to aircraft systems.
- Controls and Indicator Interfaces - Sense various APU operating parameters and furnish signals to the APU Electronic controller.
- APU Control System - Receives inputs from the flight station and signals from the APU into an APU Electronic Controller which provides control over the APU to effect appropriate levels of operation.
- APU Compartment Interfaces - Provide required mounting, APU engine compartment cooling and ventilation airflow, APU engine exhaust system connections and pneumatic system connections.

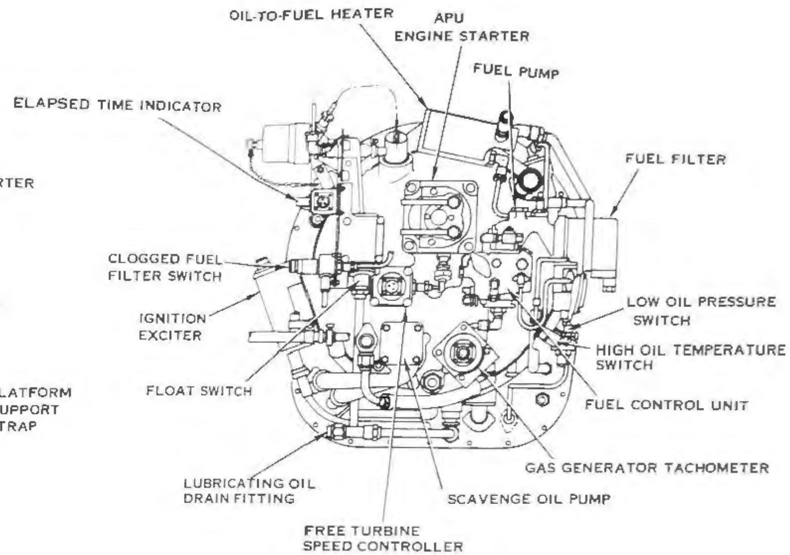
This handbook contains operational descriptions for the systems outlined above. Information on each system is contained in a separate section of this handbook and an additional section provides overall APU system troubleshooting guidelin

Auxiliary Power Unit

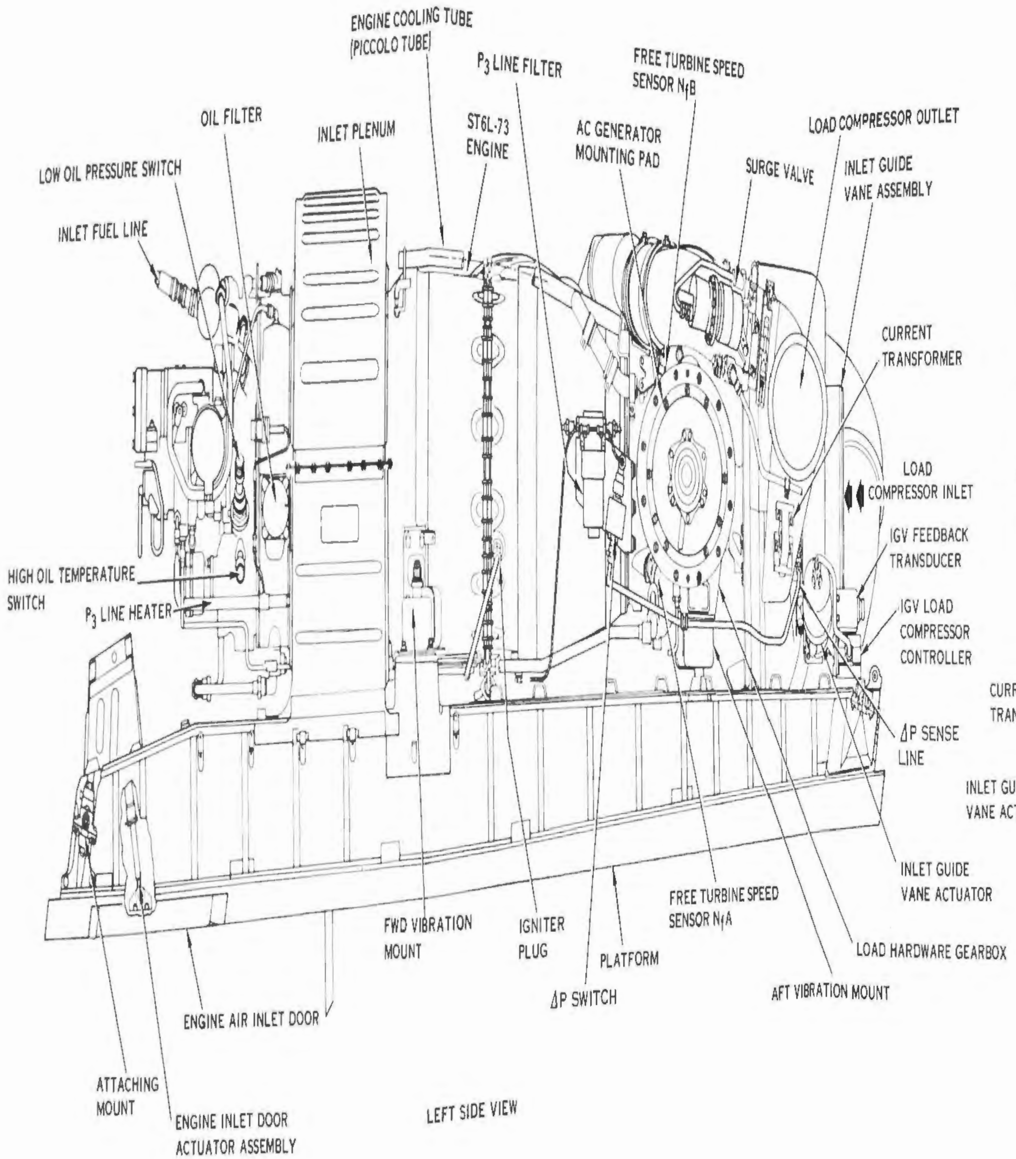
The free turbine engine satisfies the power demands of the load compressor system. Energy from the engine gas generator drives the load compressor hardware through the free turbine. The free turbine and load hardware (load compressor, cooling fan and ac generator) operate at a constant speed to maintain a generator frequency of 400 Hz. Free turbine constant speed is achieved by increasing or decreasing the gas generator speed to match the power loads



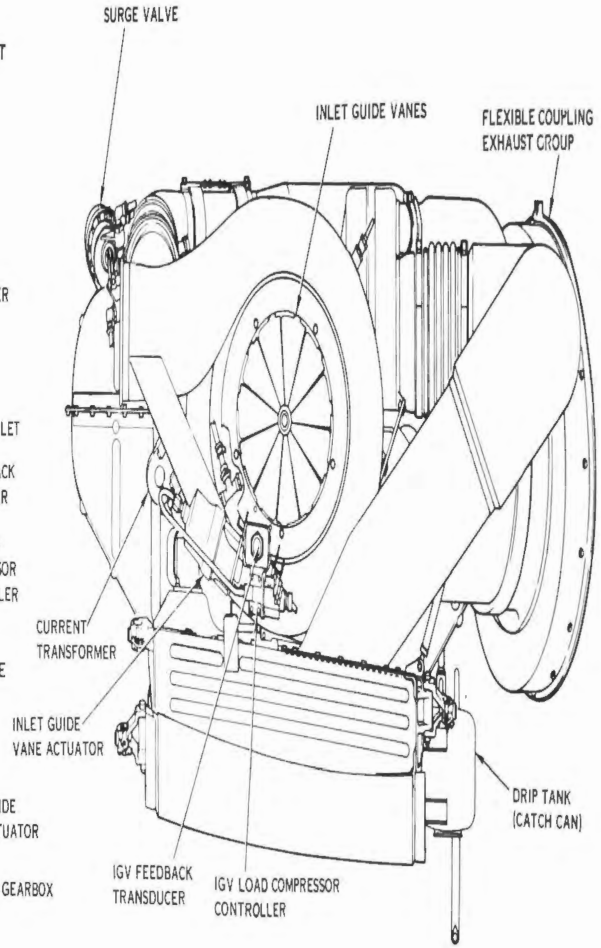
RIGHT SIDE VIEW



FORWARD END



LEFT SIDE VIEW



AFT END (LOOKING FORWARD)

AUXILIARY POWER UNIT
FIGURE 1

on the APU. If the pneumatic and electrical loads on the APU exceed the power available in the engine, inlet guide vanes partially choke the load compressor inlet to reduce the pneumatic supply while the electrical supply is maintained at a constant frequency. The inlet guide vane (IGV) assembly also maintains constant free turbine speed (N_f) during transient operations.

The APU includes an aircraft mounting platform, the bottom of which becomes a portion of the aircraft skin. When installed in the aft end of the aircraft, this skin forms a central part of the fuselage. Air for engine combustion enters through the bottom front of the platform through the engine inlet door. The engine gases exhaust through a muffler located on the lower right side of the aircraft tail section. Air for pneumatic systems is supplied to the load compressor through ducting from an opening on the left side of the aircraft above the horizontal stabilizer.

The load compressor supplies compressed air to aircraft pneumatic systems through an APU check valve and bleed air shutoff valve (APU isolation valve). If the bleed air shutoff valve is closed or if the demand for air flow is less than that being supplied by the load compressor, the excess compressor output is discharged through a surge valve into the APU engine exhaust.

A gearbox on the load compressor shaft drives a cooling fan and the ac generator. The cooling fan draws air through the inlet door in the platform and supplies this cooling air flow to the oil-to-air heat exchanger, the engine cooling (piccolo) tube, and the engine hot section. Air from the oil-to-air heat exchanger is exited through an ejector which draws ventilation air from the APU compartment. The ac generator (not supplied by Hamilton Standard) operates at 12,000 RPM and is rated at 90 KW, 3 phase, 400 Hz.

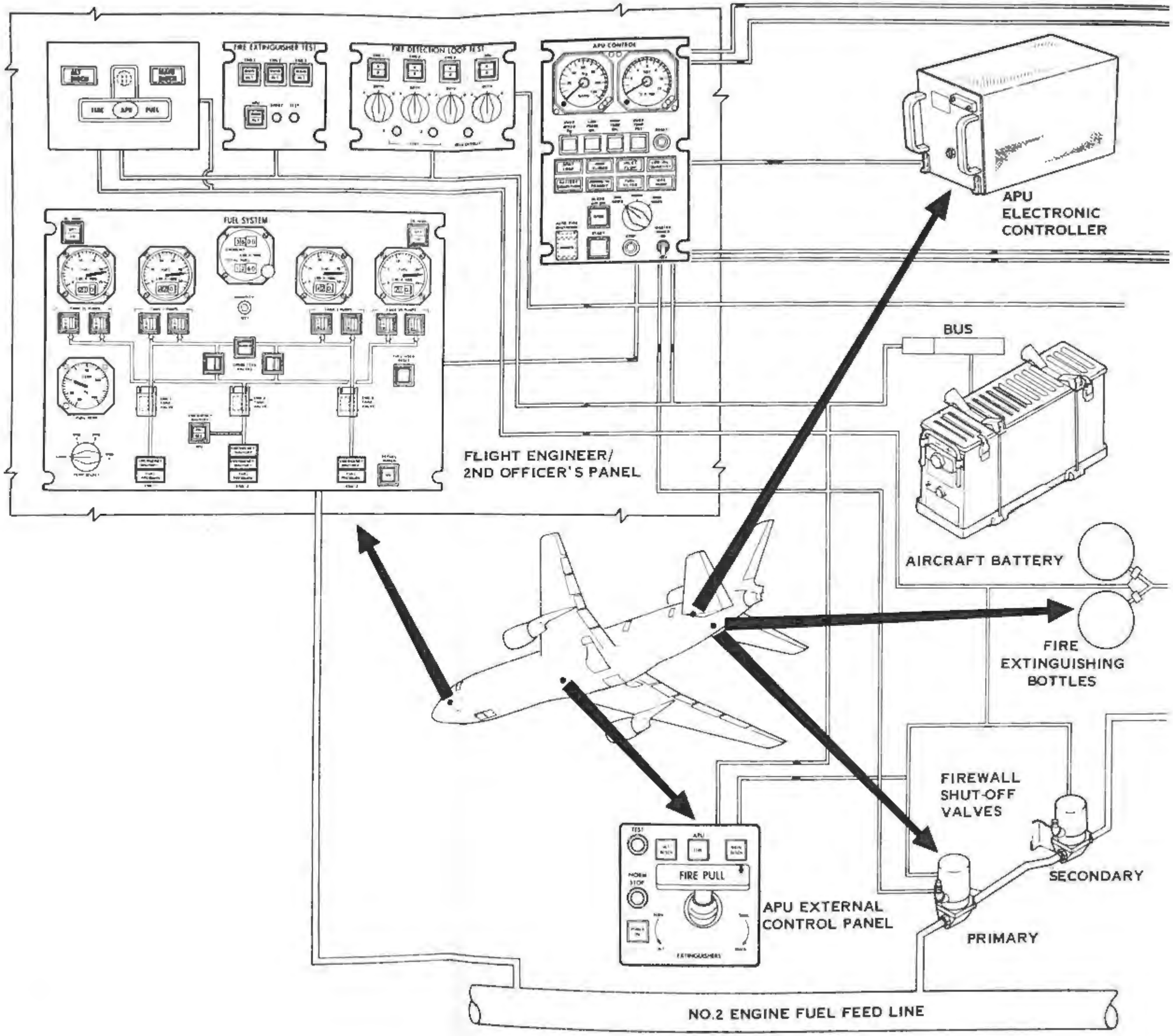
Complete automatic operation of the APU (Figure 2) is accomplished by interfacing with the APU electronic control system, the APU engine fuel control, aircraft fuel feed system shutoff valves, APU compartment fire extinguishing bottles, compartment ventilation ejector, and vent valve. Controls are provided for protection against overspeed, loss of speed sensing, loss of lubricating oil pressure, high oil temperature, high engine turbine gas temperature (TGT) and load compressor inlet icing (high delta pressure).

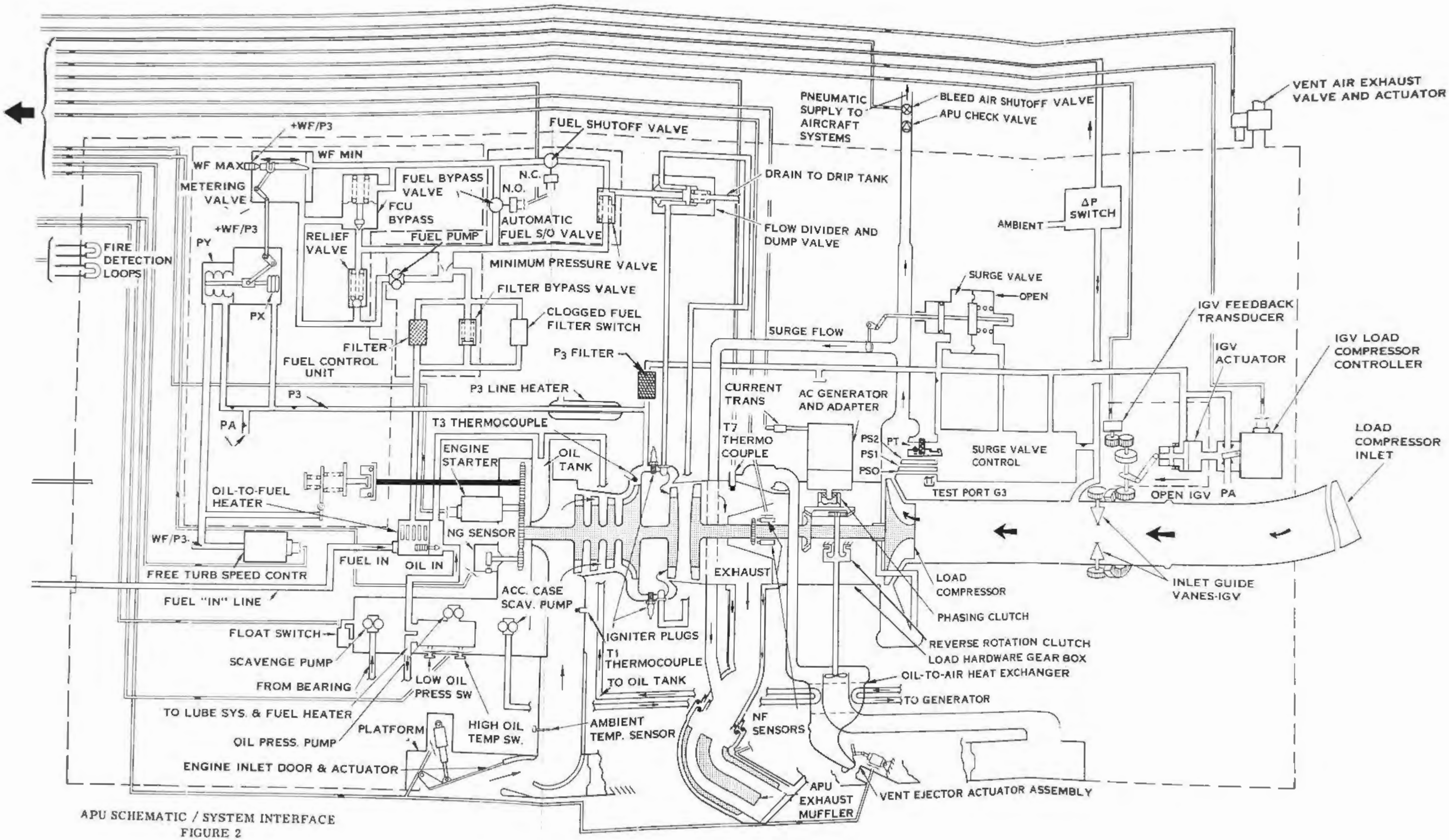
Additional major aircraft items contributing to the overall APU system and their locations are as follows:

- A 28 V dc aircraft battery located in the mid electronic service center (MESC) is required for the APU engine starter and the APU Electronic Controller.

- The APU Electronic Controller in the aft electronic service center (AESC) to the right of the aft baggage compartment.

- Fuel supplied from the aircraft number two fuel feed line.


APU
ELECTRONIC
CONTROLLER
BUS
FLIGHT ENGINEER/
2ND OFFICER'S PANEL
AIRCRAFT BATTERY
FIRE
EXTINGUISHING
BOTTLES
FIREWALL
SHUT-OFF
VALVES
SECONDARY
PRIMARY
APU EXTERNAL
CONTROL PANEL
FIRE PULL
NO.2 ENGINE FUEL FEED LINE



APU SCHEMATIC / SYSTEM INTERFACE
FIGURE 2

- An external APU control panel on the underside of the aircraft.
- The APU CONTROL panel, located on the Flight Engineer/Second Officer's panel.

APU CONTROL Panel

The APU CONTROL panel (Figure 3) located on the Flight Engineer/Second Officer's panel consists of the following items:

Instrument Gages

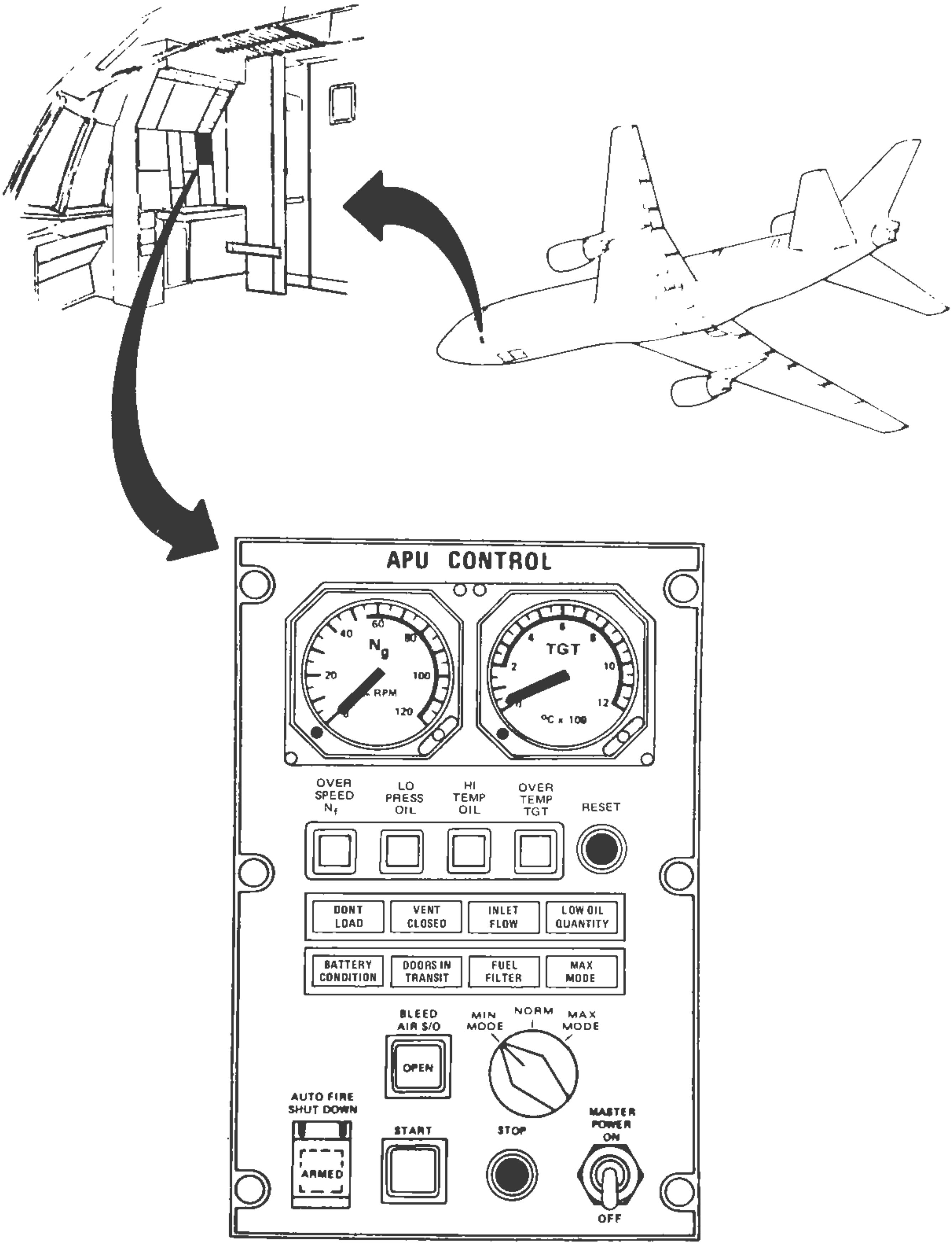
Two instrument gages are provided to monitor the APU engine during start and engine operation.

• N_g %rpm	Normal operating range is 90 to 100% gas generator speed. Test switch on indicator drives pointer to 100%.
• TGT °Cx100	Normal operating range is 700°C to 1050°C turbine inlet temperature. Test switch on indicator drives pointer to 1100°C.

Fault Flag Indicators

Each of the four fault flag indicators consists of a magnetic flag and two coils. When the trip coil is energized, the flag appears in a window of the indicator and remains there until the reset coil is energized. Trip signals are received from the APU Electronic Controller when an automatic fault shutdown is initiated. Flag operation is tested by a switch on the Flight Engineer/Second Officer's control panel, but no shutdown results. The reset switch resets all flags provided the master power switch is ON supplying power to the circuits. A tripped fault flag will not prevent a start, however, certain other protective shutdown modes that do not trip flags may prevent an APU engine start.

OVERSPEED N_f	• Trips when free turbine speed exceeds 110%, or N_{fA} sensor fails. • A seized free turbine assembly • A power interrupt during engine coast down
LOW PRESS OIL	• Trips after Ng has reached 55% if oil pressure is less than 50 psig for longer than 10 seconds. • May trip on coastdown during a power interrupt • Ng above 55% and low oil pressure • Switch is not connected or switch is inoperative



APU CABIN CONTROL PANEL
FIGURE 3

- HIGH TEMP OIL
  - Flag drops when oil temperature exceeds 245°F.
- OVER TEMP TGT (ED724438-8 ECU)
  - Trips when turbine gas temperature exceeds either 760°C when N_g is less than 55% or 1065°C when N_g is greater than 55%.
- OVERTEMP TGT (ED724438-10 ECU)
  - Trips when turbine gas temperature exceeds either 760°C when Ng is less than 70% or 1065°C when Ng is greater than 95% and a proportionate temperature level between these speeds.

Annunciator Lights

Seven of the eight annunciator lights located below the fault flags are without authority and only relate a condition. They cannot initiate a shutdown or prevent a start attempt. The remaining annunciator light (inlet flow) indicates a fault shutdown has occurred.

- DONT LOAD
  - Inlet door is open and 28 V dc power supplied to the APU Electronic Controller
  - Free turbine speed is less than 95% or above 105%.
  - Any one of the fault shutdowns has occurred
- VENT CLOSED
  - APU compartment vent valve is closed.
- INLET FLOW
  - ΔP shutdown due to blockage of air flow to the load compressor inlet duct. Disabled when MAX select relay is energized.
- LOW OIL QUANTITY
  - Oil is approximately 2 quarts down from full mark. May illuminate during takeoff attitude.
- BATTERY CONDITION
  - Battery is too weak or overheated for a good start.
- DOORS IN TRANSIT
  - Inlet door or ejector door is not full open or not full closed.
- FUEL FILTER
  - Delta P across APU fuel pump filter is greater than 1.25 psi.
- MAX MODE
  - Inlet guide vanes of the load compressor are commanded full open by energized MAX mode relay.

Mode Select Switch

An APU mode select switch has three positions; MIN MODE, NORM and MAX MODE. MAX MODE is also automatically selected when a main engine start relay is activated if the bleed air shutoff valve is open.

NOTE: The MAX MODE select position on the APU CONTROL panel should only be used during the last phase of the main engine thrust reverser ground check, or during trouble shooting of the APU inlet guide vane section.

APU Start/Stop Procedures

Once a start cycle has been initiated, (APU fuel boost pump on, MASTER POWER switch (on the APU CONTROL panel) selected ON and the START switchlight pressed and held in for two seconds), the APU system (Figure 2) has automatic controls for the start schedule sequencing, maintaining normal operation within safe limits and providing automatic deceleration and the proper shutdown sequence after a stop cycle has been initiated.

CAUTION: BEFORE ATTEMPTING TO SHUTDOWN THE APU, POSITION THE MODE SELECT SWITCH TO THE MIN MODE POSITION. THE BLEED AIR S/O VALVE ON THE APU CONTROL PANEL SHOULD BE SELECTED CLOSED AND THE APU ENGINE MAINTAINED OPERATING FOR TWO MINUTES TO STABILIZE ENGINE TEMPERATURE BEFORE STOP BUTTON IS DEPRESSED. THIS PROCEDURE ALLOWS PROPER COOLING OF THE APU ENGINE THEREBY MAINTAINING THE ANTICIPATED NORMAL SERVICE LIFE OF THE ENGINE.

After pressing the STOP button, the MASTER POWER switch should not be selected OFF until the doors in transit light goes ON and then OFF, (approximately 3 minutes after the STOP button is depressed) indicating the engine has gone through the proper shutdown purge cycle and the engine inlet door is closed. The engine will decelerate to approximately 60% Ng and remain at the condition for 60 to 100 seconds after the stop button is pushed.

The APU can also be shutdown from the external APU control panel located under the center section of the aircraft. The APU should only be shut down from this station when it is absolutely necessary as there are no provisions to select MIN MODE allowing the engine temperature to stabilize before shutdown.

NOTE: To shut down the APU from this station, the external stop button should be pressed. If the NORM STOP button is used to shut the APU down, master power is not removed. The POWER ON switchlight must be pressed or the MASTER POWER switch on the cabin APU CONTROL panel must be turned off after the inlet door is fully closed.

Main Engine Start Using the APU

The APU load compressor output will start the main engine within the desired envelope providing there is no other air requirement and the APU electrical load does not exceed 15 KVA. Imposition of greater demands upon the APU could result in extended main engine starting times or APU protective shutdowns.

APU General Specifications

• APU Size (approximate)	Length 92 inches, width 52 inches, height 31 inches.
• APU Platform Size	30 inches by 90 inches.
• APU Weight with Platform (approximate)	720 pounds (less generator).
Power plant designation	ST6L-73
• Horsepower	635 at sea level, 103°F.
• Free Turbine Speed N_f (100%)	33,000 rpm (constant)
• Gas Generator Speed N_g (100%)	37,500 rpm
• N_g Electronic Topping Range	36,500 - 38,100 rpm (97-101.6%)
• N_g Governor Flyweight Topping	38,500 - 38,850 rpm
• Fuel Flow	400 lb/hr at 100% load at sea level, 103°F.
• Load Compressor Speed	33,000 rpm (constant)
• Load Compressor Output	385 lbs/min at 41 psia at 103°F, sea level with 45 KW electric load
• Comp Discharge Air Temp	360°F at 103°F day
• Cooling Fan Speed	32,869 rpm
• Cooling Fan Output	160 lbs/min at sea level at 103°F day
• Generator Speed	12,000 rpm
• Generator Output	90 KW, 3 phase, 400 Hz

APU General Specifications (continued)

- TGT Electronic Topping
  - MIN, normal and MAX mode (ED724438-8 ECU) — TGT exceeds 1918°F
  - MIN, and normal mode (ED724438-10 ECU) — TGT exceeds 1863°F
  - MAX mode (ED724438-10 ECU) — TGT exceeds 1918°F

ST6L-73 ENGINE

ST6L-73 ENGINE GENERAL DESCRIPTION

The ST6L-73 Engine (Figure 1-1 and 1-2) is a lightweight free turbine engine designed for integration with a loading unit to form a complete auxiliary power unit (APU). The engine utilizes two independent turbines; one driving a compressor in the gas generator section and the second (free turbine) driving the load compressor system. The engine is not self-sufficient since its oil systems and output shaft speed control need to be integrated into the complete APU.

Inlet air enters the engine through a plenum chamber mounted on the platform which directs air to the compressor. The compressor consists of three axial stages combined with a single centrifugal stage and assembled as an integral unit. It provides a compression ratio of 7:1.

A row of stator vanes, located between each stage of compression, diffuses the air, raises its static pressure, and directs it to the next stage of compression. The compressed air passes through diffuser pipes which turn it ninety degrees in direction and then through straightening vanes to the annulus surrounding the combustion chamber liner.

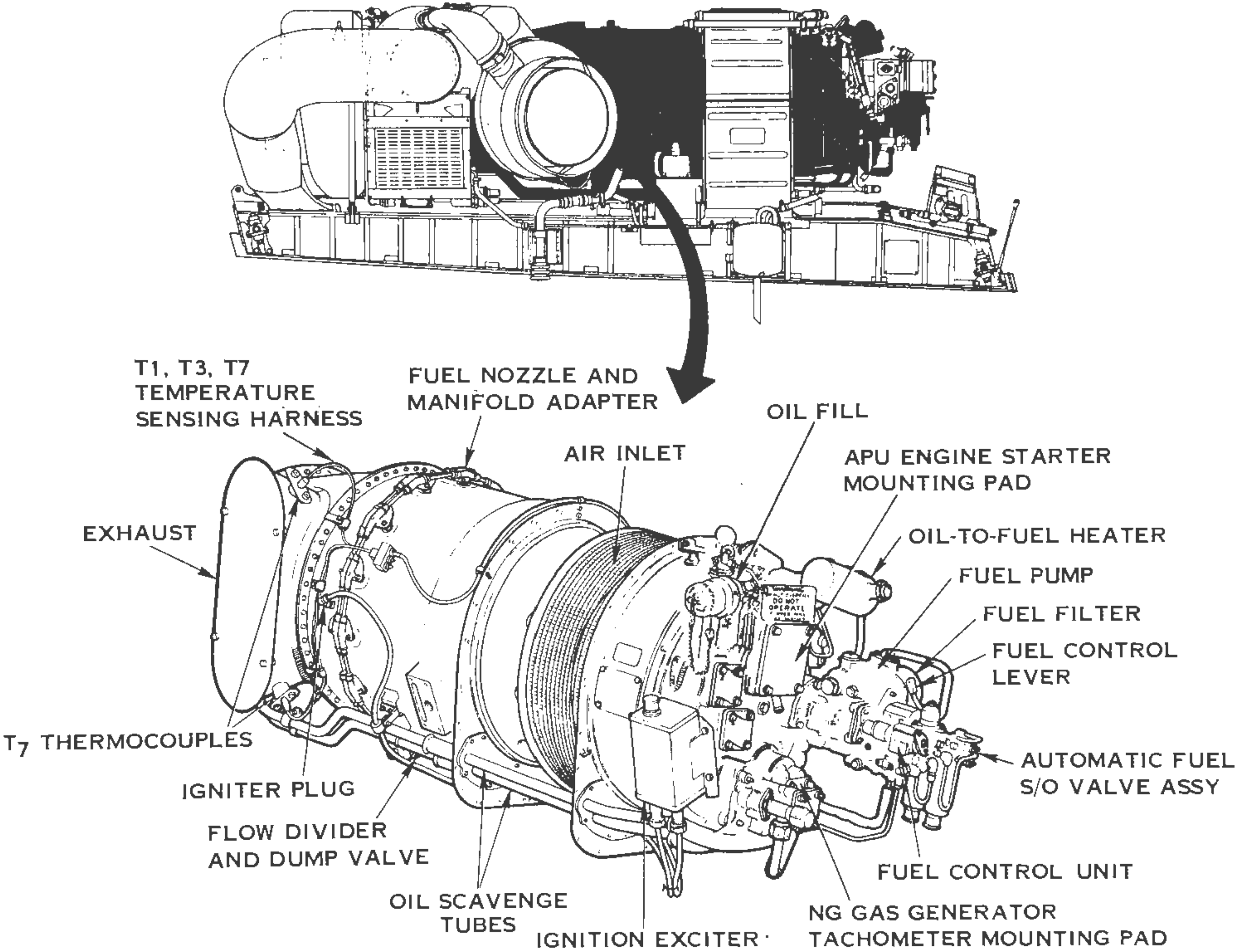
The combustion chamber liner consists of an annular weldment provided with varying sized perforations which allow entry of compressor delivery air. The flow of air changes direction as it enters and passes through the combustion chamber liner where it mixes with fuel. The flow of gases again reverses direction as it leaves the combustion chamber liner.

Fourteen nozzle assemblies, supplied by a dual fuel manifold, inject fuel into the combustion chamber liner. The mixture ignites by two igniter plugs which protrude into the combustion chamber liner. The resultant gases expand from the combustion chamber liner, reverse direction and pass through the compressor turbine guide vanes to the compressor turbine. The turbine guide vanes ensure that the expanding gases impinge on the turbine blades at the proper angle, with a minimum loss of energy. The still expanding gases pass forward through a second set of stationary guide vanes to drive the free turbine.

The free turbine drives the load hardware gearbox and load compressor through a quill shaft splined to the power turbine shaft coupling.

All engine driven accessories mount on the accessory gearbox located at the forward end of the engine. These are driven by the compressor by means of a coupling shaft which extends the drive through a conical tube in the oil tank center section.

The engine oil supply is contained in an integral oil tank which forms part of the compressor inlet case. The tank has a total oil capacity of 2.3 U.S. gallons and is provided with an oil level sight glass and drain plug.



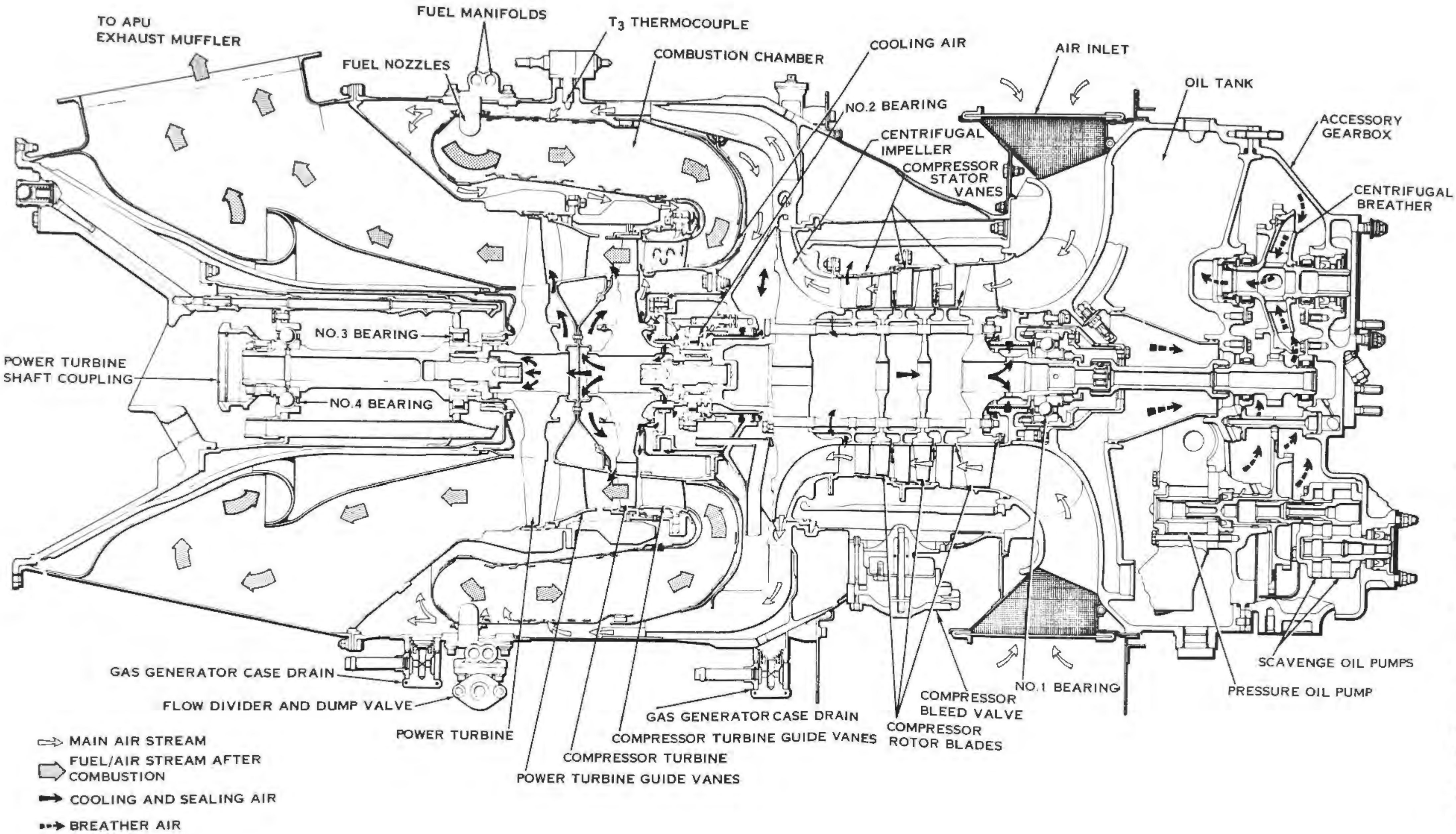
ST6L-73 ENGINE
FIGURE 1-1

The fuel, supplied to the APU engine from aircraft systems, is pressurized and regulated in the APU by an engine driven fuel pump and fuel control unit.

ST6L-73 Engine Specifications

• Max Rating at 59°F (15°C) Inlet Temp	0.585* at 820 SHP
• Max Rating at 103°F (40°C) Inlet Temp	0.611* at 720 SHP
• 75% Max Rating at 59°F (15°C) Inlet Temp	0.627* at 615 SHP
• 75% Max Rating at 103°F (40°C) Inlet Temp	0.670* at 540 SHP
• Engine Type	Free Turbine
• Type of Combustion Chamber	Annular
• Compressor Ratio	7.0:1
• Free Turbine Rotation (Viewed from FWD End)	Clockwise
• Free Turbine Max Permissible rpm	33,000 (steady state)
• Engine Diameter	19 inches
• Engine Length	52.2 inches
• Oil Consumption, Max Average	0.1 lb/hr
• Dry Weight (including standard equipment)	300 lb

* Specific fuel consumption (lb/SHP/hr)



ST6L-73 ENGINE AIR FLOW SCHEMATIC
FIGURE 1-2

MAJOR SYSTEMS

Air System

The engine has four basic air systems (see Figure 1-2), supplied from the main air stream through the engine. These are: the compressor control bleed air system, the turbine disk and compressor turbine stator vane cooling system, the bearing compartment air seal system, and two P_3 tap pressure sources that are used to actuate certain APU pneumatic control functions.

Fuel System

The basic fuel system consists of a single power driven rotary fuel pump, a fuel control unit, an automatic fuel shutoff valve assembly, a flow divider and dump valve, and a dual fuel manifold with 14 fuel nozzle assemblies. Two drain valves are provided on the gas generator case to ensure drainage of residual fuel after engine shutdown and for proper fuel drainage in case of a false start.

Ignition System

The engine ignition system consists of an ignition exciter mounted on the engine accessory gearbox and connected by two shielded electrical cables to two ignitor plugs in threaded bosses of the gas generator case.

Lubrication System

The lubrication system provides a constant supply of clean lubricating oil to the engine bearings, the load hardware gearbox and all accessory drive gears. The oil lubricates and cools the bearings and conducts any extraneous matter to the main oil filter where it is prevented from circulating further. Calibrated oil nozzles used on the main engine bearings ensure that an optimum oil flow is maintained for all operating conditions.

The oil tank is an integral part of the compressor inlet case and is located in front of the accessory gearbox. The tank has a total capacity of 2.3 U.S. gallons of which approximately 2.0 gallons is usable oil. This capacity provides for an expansion space of approximately 0.5 gallon, and is sufficient to meet all normal operating requirements.

The oil tank has an oil filler neck and an oil level sightglass which protrudes through the accessory gearbox housing. A drain plug is located in the bottom of the accessory gearbox.

Oil circulates from the integral oil tank through the engine lubricating system by a self-contained gear-type pressure pump located in the lowest portion of the oil tank. The oil pump consists of two gears contained in a cast housing, bolted to the front face of the accessory diaphragm. It is driven by the accessory

gearshaft which also drives the internal scavenge pump. A removable screen is provided at the oil pump inlet. The oil pump body incorporates a circular mounting boss to accommodate the check valve located in the end of the filter housing. The oil is pumped through the spring-loaded check valve into the filter housing.

Engine Controls

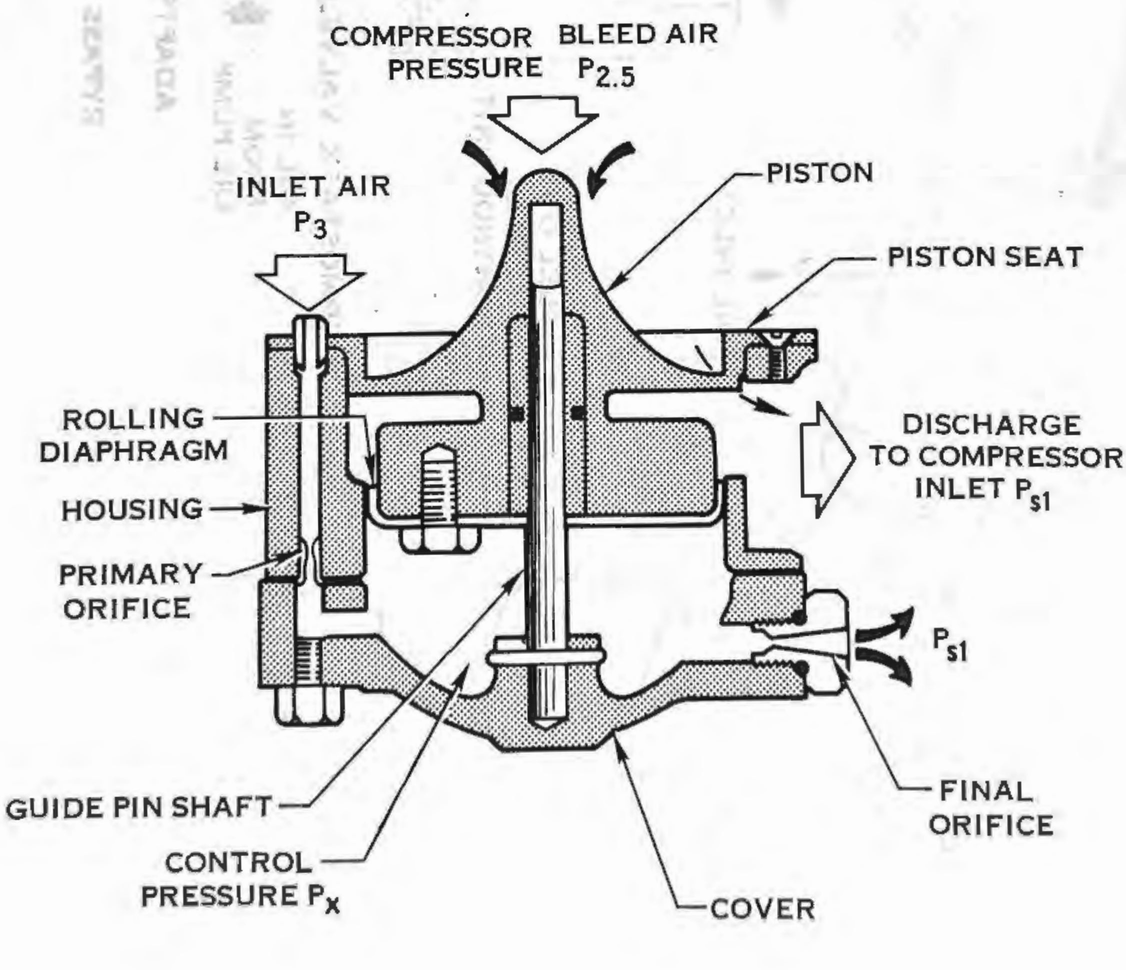
On the APU, the power control lever is locked in the maximum position and power is modulated by varying the amount of air bled from the pneumatic section of the fuel control unit. The air bleed is regulated by the free turbine speed controller which under command from the APU Electronic Controller, acting to maintain the free turbine speed constant, varies the gas generator speed to compensate for changes in load on the output shaft. The free turbine speed signal is the result of eleven ferromagnetic segments on the rotating flange of the free turbine shaft coupling passing by the sensing end of two free turbine speed sensors inducing an impulse signal which is transmitted to the APU Electronic Controller.

Compressor Bleed Valve Description and Operation

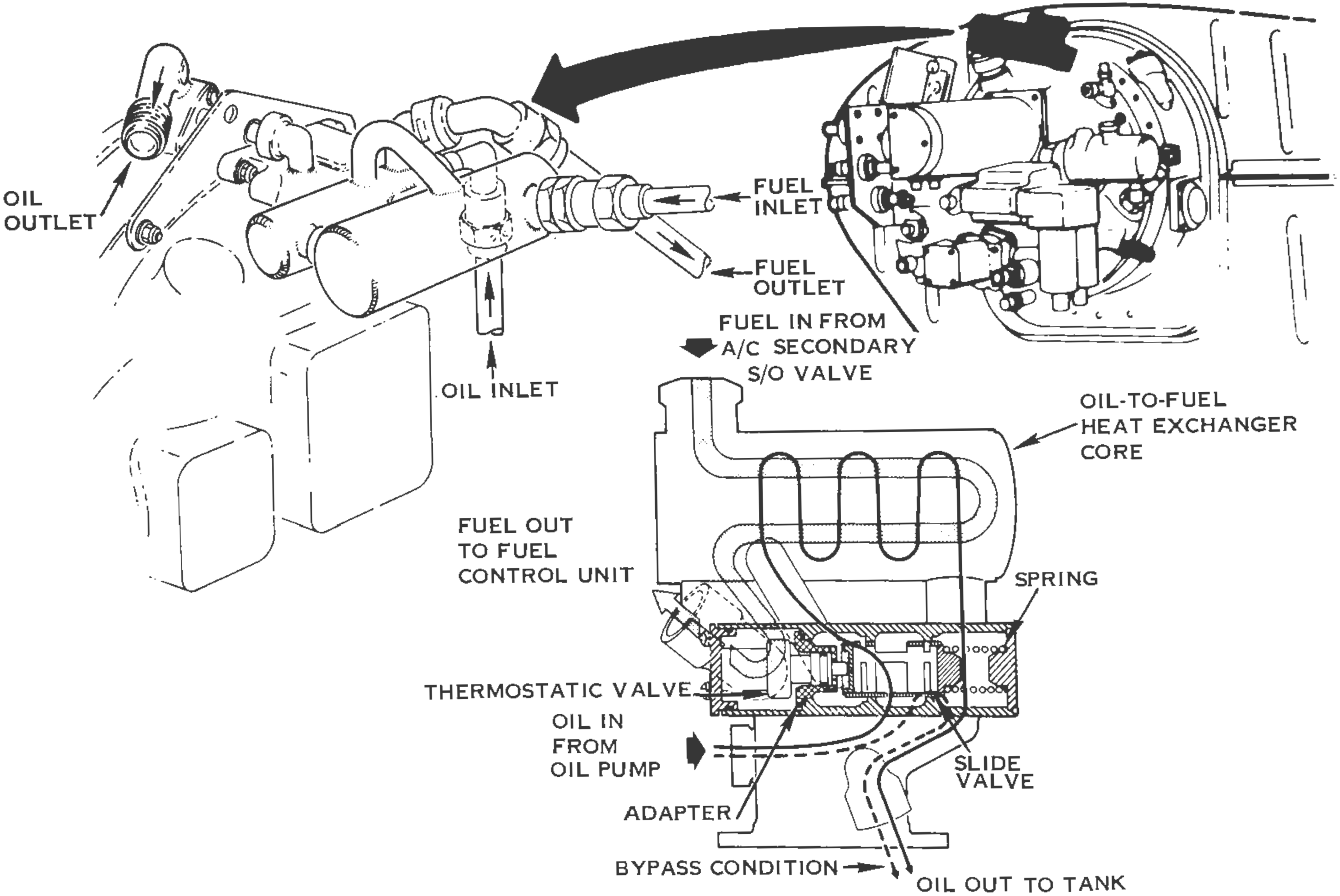
The compressor control bleed air system consists of a piston type compressor bleed valve (Figure 1-3) located on the underside of the compressor housing. The bleed valve prevents compressor stall at low engine speeds by automatically opening a port in the gas generator case to bleed off interstage compressor air ($P_{2.5}$). This port closes gradually as higher engine speeds are attained.

The compressor bleed valve piston is supported in the bore of the housing by a rolling diaphragm which permits the piston full travel in either direction to open or close the port, while at the same time, effectively sealing the control pressure chamber. A spring pin inserted in the base of the bleed valve serves to align the P_3 supply passageway with that in the gas generator case.

Compressor discharge air (P_3) tapped off and metered through a fixed orifice in the valve, flows across the control piston, and out to the inlet plenum (P_{s1}) through a final orifice. The control pressure (P_x) between the two orifices acts upon the piston, so that when P_x is greater than $P_{2.5}$, the bleed valve closes. In the closed position, the port is sealed off by the piston.



COMPRESSOR BLEED VALVE
FIGURE 1-3



OIL-TO-FUEL HEATER
FIGURE 1-4

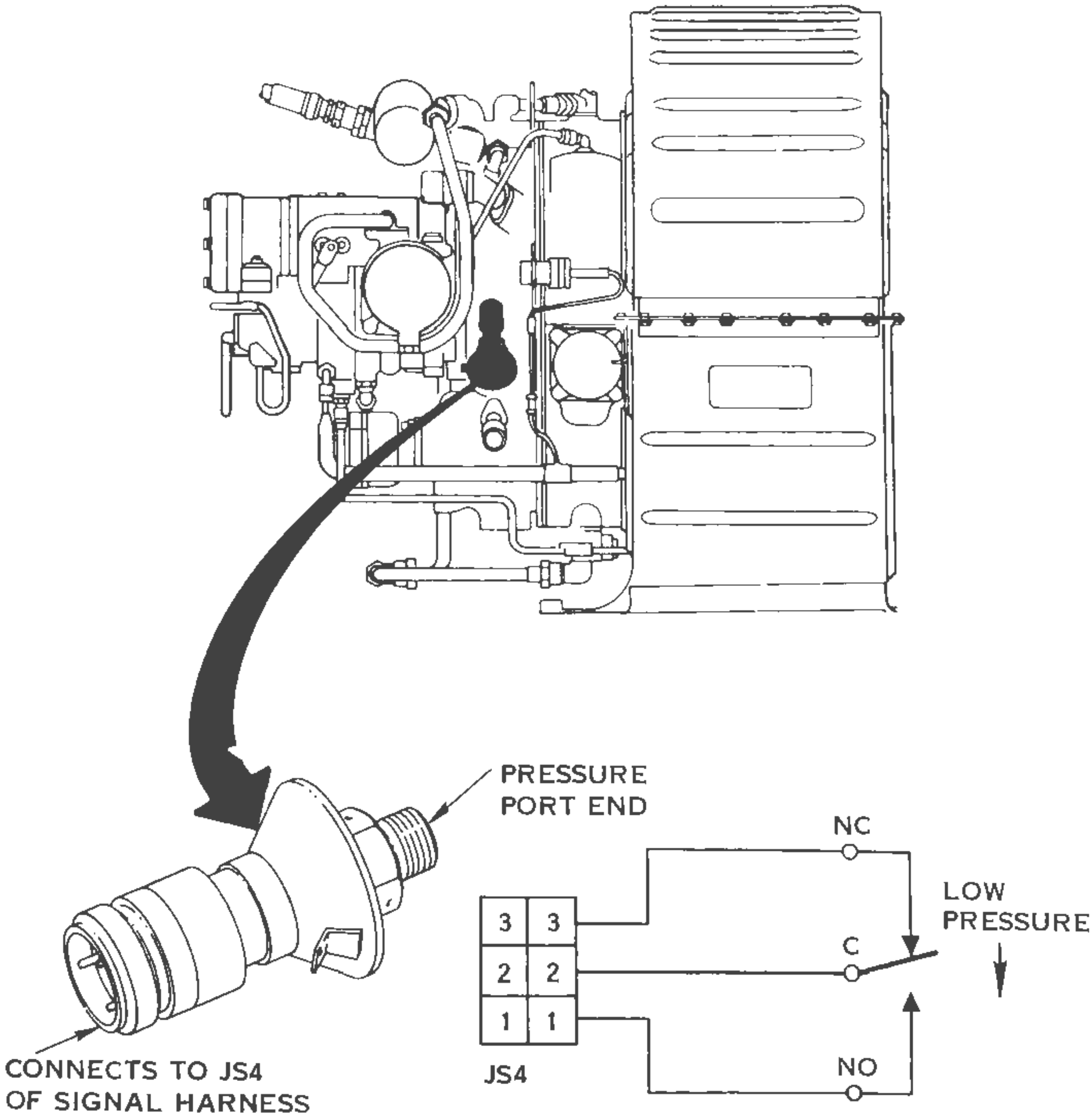
Oil-to-Fuel Heater Description and Operation

The oil-to-fuel heater (Figure 1-4) is basically a thermostatically controlled heat exchanger using engine oil heat to maintain fuel temperature between 70 and 90 degrees F. A thermostatic valve element and spring-loaded slide valve make up the regulating assembly. The fuel temperature sensed by the thermostatic valve expands or contracts driving the sleeve valve as required to regulate the flow of oil to the oil-to-fuel heat exchanger core. The heater mounts near the top of the engine accessory gearbox.

Low Oil Pressure Switch Description and Operation

The low oil pressure switch (Figure 1-5) is a normally closed switch that contains a pressure sensing diaphragm hermetically sealed in a stainless steel case.

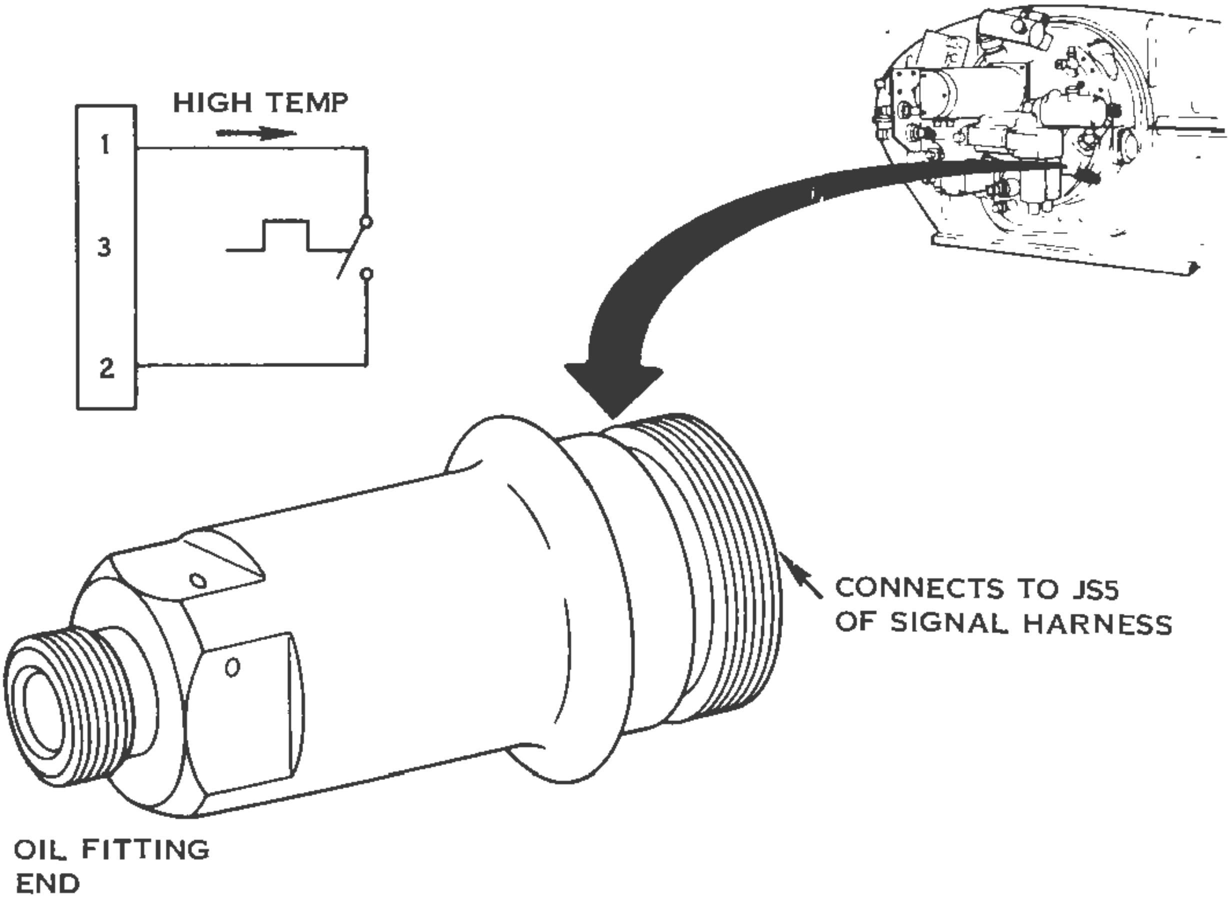
In the event that oil pressure drops below 50 psig, a ground signal through the signal harness and aircraft wiring to the APU Electronic Controller is removed. After 10 seconds, if Ng is greater than 55%, the low pressure oil flag drops. During normal operation, if low oil pressure persists for more than 10 seconds, an automatic APU shutdown by the APU Electronic Controller occurs and the Controller sets the LOP flag. The LOP circuitry is inhibited below 55% Ng on start up and by the presence of any other protective shutdown (fault) signal.



LOW OIL PRESSURE SWITCH
FIGURE 1-5

High Oil Temperature Switch Description and Operation

The high oil temperature switch (Figure 1-6) mounts on the accessory gearcase and consists of a bimetallic element and a normally open electrical switch mounted in a glass insulated stainless steel case. Whenever oil temperature reaches or exceeds 245 degrees F, the bimetallic element actuates the switch sending a signal through the signal harness and aircraft wiring that drops the HIGH TEMP OIL flag on the APU CONTROL panel. Actuation of the switch also sends a signal to the Electronic Controller which initiates an automatic shutdown of the APU.

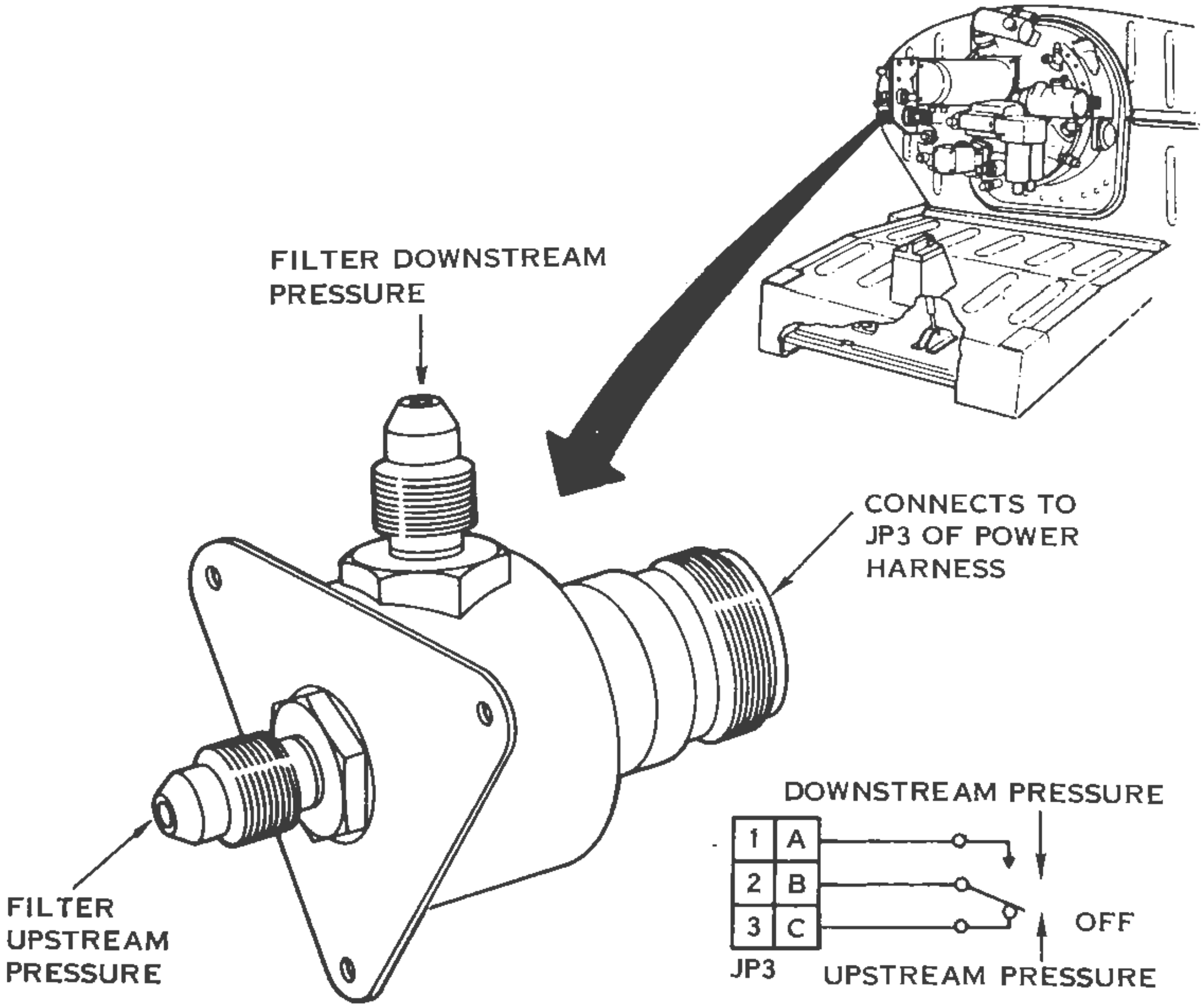


HIGH OIL TEMPERATURE SWITCH
FIGURE 1-6

Clogged Fuel Filter Switch Description and Operation

The clogged fuel filter switch (Figure 1-7) is a normally open switch that contains a spring-loaded differential pressure sensing diaphragm. In the event that the filter in the power driven rotary fuel pump becomes clogged, the clogged fuel filter switch actuates when the differential pressure across the filter reaches or exceeds 1.25 psi. When the switch closes, the power harness and aircraft wiring form a closed circuit which lights the FUEL FILTER annunciator light on the APU CONTROL panel in the flight station.

Connections to the APU power harness are made through pins 1 and 2. Pins 1 and 2 are normally open at a pressure differential less than 1.25 psi.

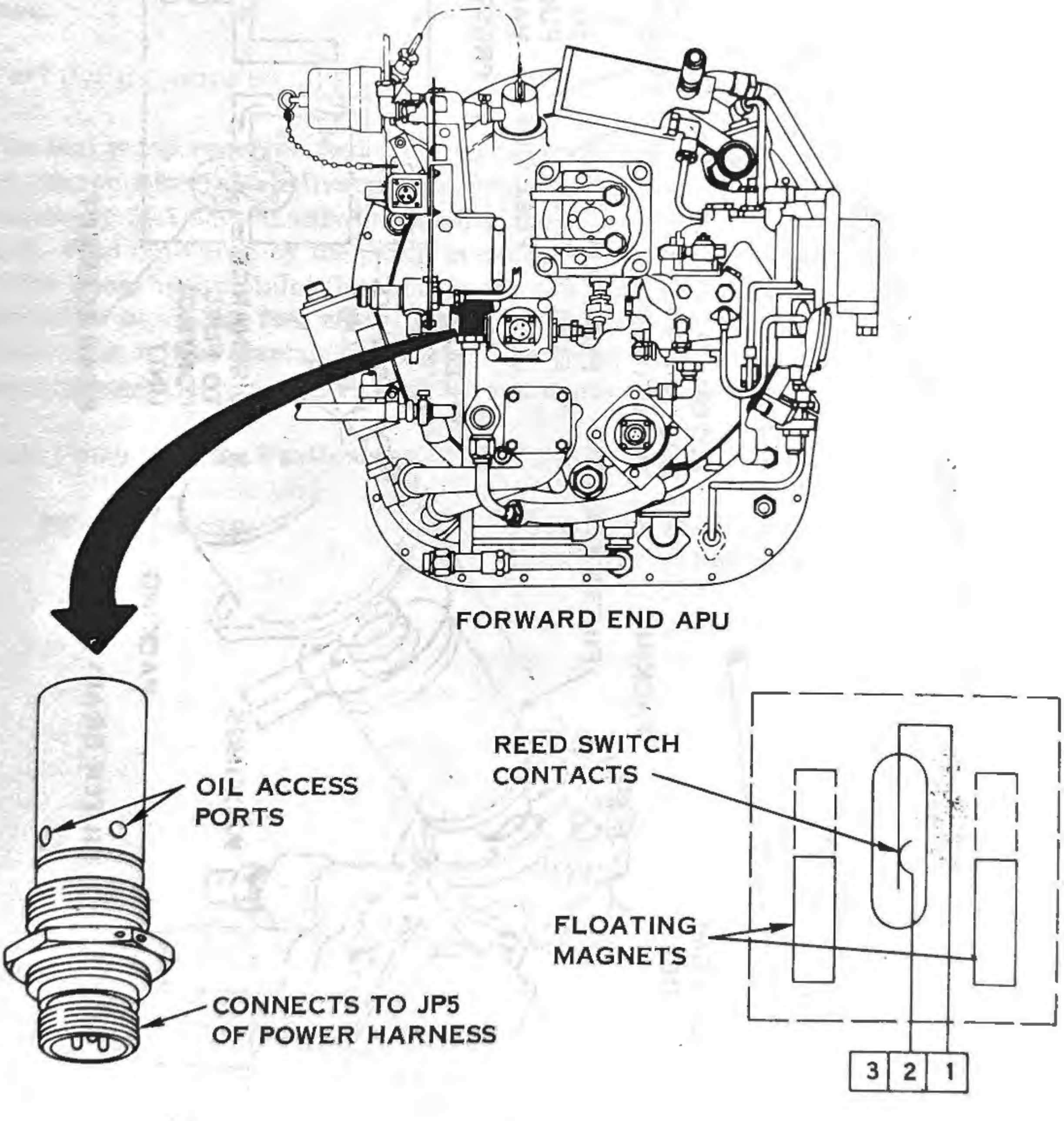


CLOGGED FUEL FILTER SWITCH
FIGURE 1-7

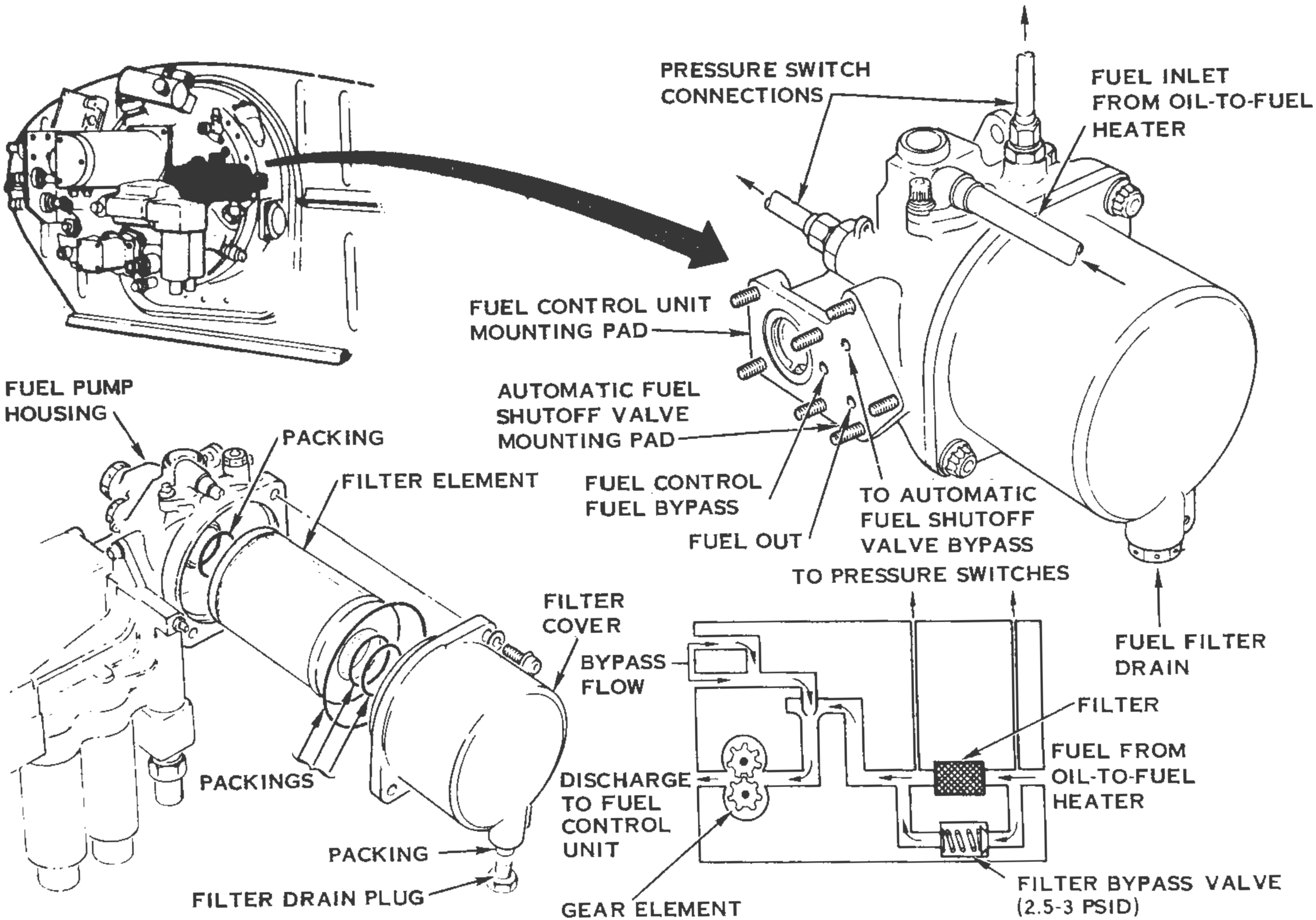
Float Switch (Low Oil Quantity) Description and Operation

The float switch (Figure 1-8) mounts on the accessory gearcase and consists of a reed type switching element and a magnetized float assembly. At the proper oil level the switch is open. The switch closes when the oil quantity in the tank decreases below approximately 3.5 quarts down from full mark. The closed switch sends a signal through the power harness and aircraft wiring completing a circuit to the APU CONTROL panel that lights the LOW OIL QUANTITY annunciator light.

NOTE: To prevent a false low quantity indication during "take-off" (due to aircraft attitude) the low oil quantity circuit is now wired through the aircraft nose gear steering relay number 2. (Refer to service bulletin No. 093-49-023.)



FLOAT SWITCH
FIGURE 1-8



FUEL PUMP
FIGURE 1-9

Fuel Pump Description

The fuel pump (Figure 1-9) is a positive displacement gear-type pump mounted on the accessory gearbox. The pump body incorporates a filter housing with a removable 10 micron filter element filtering the fuel entering the pump. A filter bypass valve provides an alternative path for unfiltered fuel whenever filter blockage causes a pressure build-up.

The fuel pump extends the drive from the accessory gearbox to the fuel control unit mounted in tandem with it. A bypass return port in the pump mounting pad matches up to the fuel control unit internal bypass passage. The automatic fuel shutoff valve assembly also mounts on the fuel pump, adjacent to the fuel control unit. Fuel delivery and bypass return passages in the pump match up with similar passages in the automatic fuel shutoff valve assembly mounting face.

Fuel Pump Operation

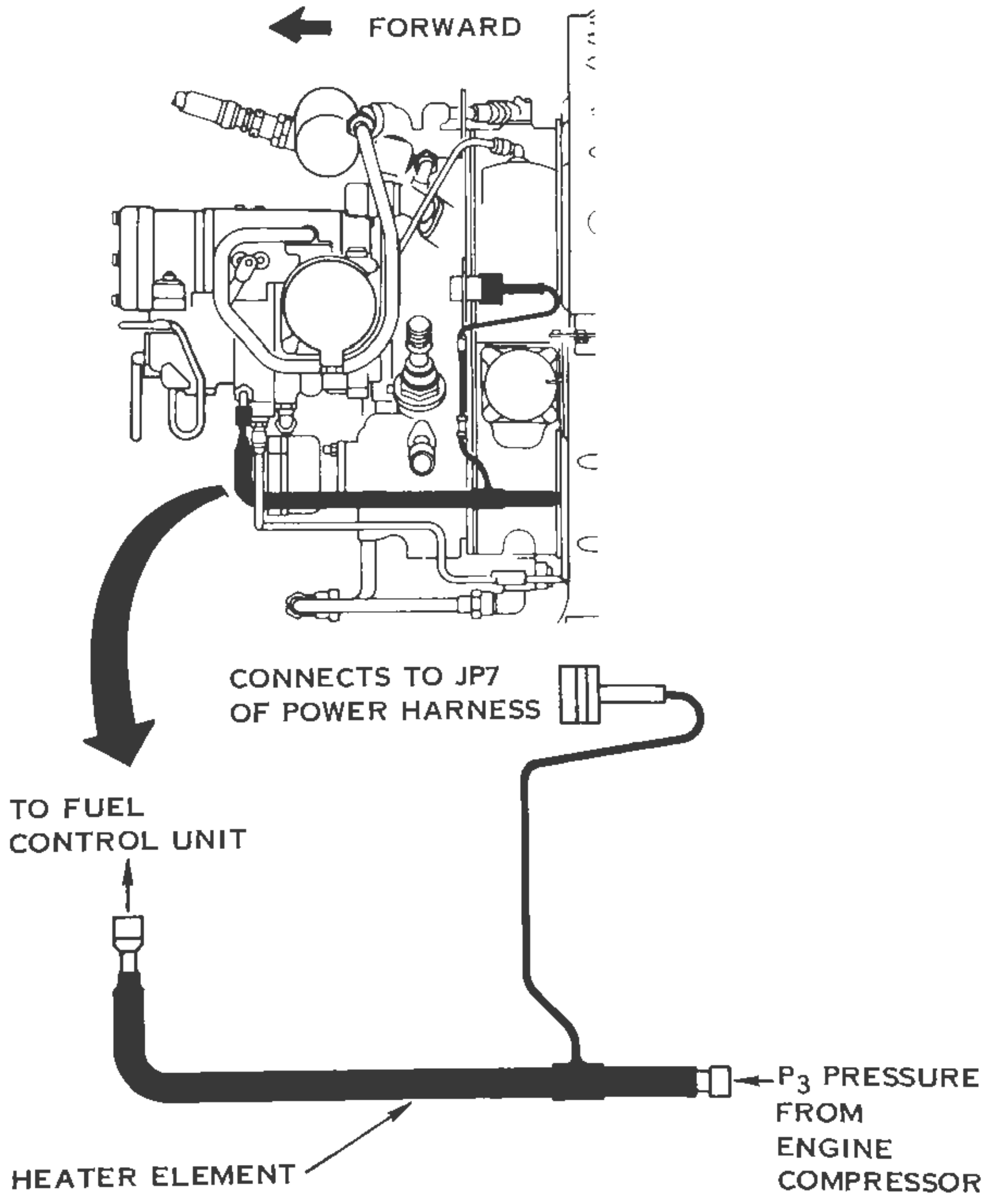
The fuel pump receives fuel from an aircraft fuel tank, passes it through a 10 micron filter and delivers it under pressure through a passage in the automatic fuel shutoff valve assembly and an external tube to the fuel control unit. Fuel delivered by the pump in excess of engine requirements is returned to the pump bypass inlet through the bypass passage in the fuel control unit. When the automatic fuel shutoff valve assembly is de-energized at engine shutdown or at initial startup, the fuel delivered by the pump is returned to the pump inlet through the bypass valve in the automatic fuel shutoff valve assembly.

Fuel Pump Leading Particulars

• Rated Capacity	156 lb/hr at 75 psig and 810 rpm 1183 lb/hr at 900 psig and 6350 rpm

P_3 Line Heater Description and Operation

The P_3 line heater (Figure 1-10) is an electric heater element that encases the external portion of the P_3 pressure tube extending from the compressor fire-seal to the fuel control unit. The P_3 line heater maintains tube temperature above freezing thus preventing ice formation from blocking P_3 supply pressure.



P3 LINE HEATER
FIGURE 1-10

Fuel Control Unit Description

The fuel control unit (Figures 1-11 and 1-12) mounts on, and is geared to the power driven rotary fuel pump. The unit is a hydro-pneumatic control consisting of a pneumatic computing section linked to a fuel metering section. The computing section contains lever operated valves driven by a flyweight assembly and connected by pneumatic passageways to a pressure sensing chamber. The fuel metering section consists of a metering valve, FCU bypass valve and a high pressure relief valve.

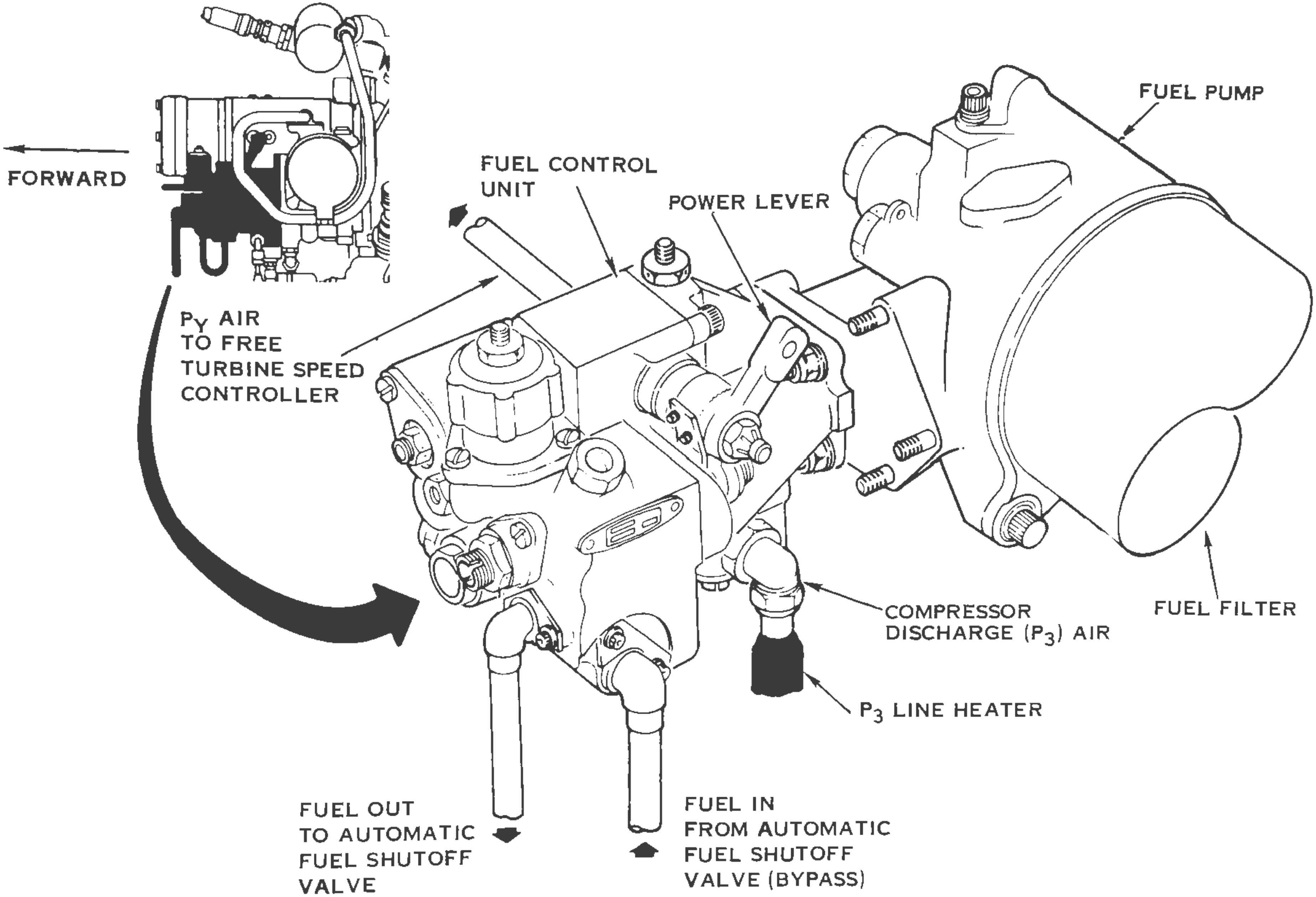
Pneumatic P_3 inlet pressure reduced through an orifice and altered by a bleed orifice becomes P_x pressure. P_x pressure reduced through another orifice becomes P_y pressure.

N_g governor flyweights receive rotational inputs from the pump and apply these inputs against a governor lever which in turn is spring-loaded against a power lever. P_y pressure is supplied to a P_y bleed nozzle at one end of the governor lever. The power lever is preset in a fixed position. The pressure sensing chamber compares P_x with P_y pressure. P_x pressure surrounds an evacuated acceleration bellows joined by a rod to a governor bellows that seals off P_y pressure. The bellows rod connects to a cross shaft and torque tube which transmits the pneumatically sensed signals to the metering valve.

Fuel passageways connect P_1 pump outlet fuel pressure to the metering valve and to a spring-loaded high pressure relief valve. The metering valve is a variable orifice with inlet chamber and outlet pressure (P_2) connected to the FCU bypass valve. The FCU bypass valve is a diaphragm-operated poppet valve with its outlet connected to the relief valve outlet and to the pump bypass return port. Fuel pressure from the metering valve outlet flows to the automatic fuel shutoff valve assembly.

Fuel Control Unit Metering Section Operation

The metering section maintains a constant differential pressure across a metering valve to establish a rate of fuel flow. Fuel pump outlet pressure (P_1) is supplied to the metering valve which determines fuel flow through a variable orifice. Metered fuel pressure (P_2) is sensed by the bypass valve which compares P_1 and P_2 pressures across a spring-loaded diaphragm that operates a poppet valve in the bypass line. When open, bypass pressure (P_o) returns fuel from the metering valve inlet to the bypass inlet on the pump. Fuel flow to the engine is a function of metering valve position only, as the FCU bypass valve maintains an essentially constant differential fuel pressure across the metering valve orifice regardless of variations in fuel inlet or fuel discharge pressures.



FUEL CONTROL UNIT
FIGURE 1-11

A high pressure relief valve prevents a build-up of P_1 pressure in the fuel control unit. The relief valve is a spring-loaded ball that remains closed against its seat until inlet fuel pressure (P_1) overcomes spring force opening the valve and allowing fuel to return to the pump. As soon as inlet pressure is reduced the relief valve closes.

Fuel Control Unit Computer Section Operation

Basic engine speed control is achieved by varying P_y pressure. Although the power lever and governor lever, can vary the P_y pressure, normally the APU Electronic Controller varies P_y pressure at the P_y bleed orifice of the free turbine speed controller. P_y pressure is proportional to fuel flow; as P_y pressure increases, fuel flow increases, and as P_y pressure decreases, fuel flow decreases.

When the power lever is placed in the max position, it provides a spring force against the governor lever and since the power lever is fixed at max position, for normal operation the governor can provide only overspeed protection. The other end of the governor lever operates against the P_y bleed nozzle.

As the drive shaft revolves, it rotates a table on which the governor weights are mounted. As gas generator rpm (N_g) increases, centrifugal force causes the weights to apply increasing force against the P_y bleed nozzle. The P_y bleed nozzle will open if N_g reaches mechanical topping (max rpm limit) which is a flyweight force sufficient to overcome the governor spring force.

The bellows assembly consists of an evacuated (acceleration) bellows and a governor bellows connected by a rod. The acceleration bellows provides an absolute pressure reference and the governor bellows is secured to the housing such that it functions like a diaphragm. Movement of the bellows rod is transmitted to the metering valve by the cross shaft which results in an increase or decrease in the force of the torque tube. The torque tube is preloaded to provide a force to close the metering valve while both bellows act against this force to open the metering valve.

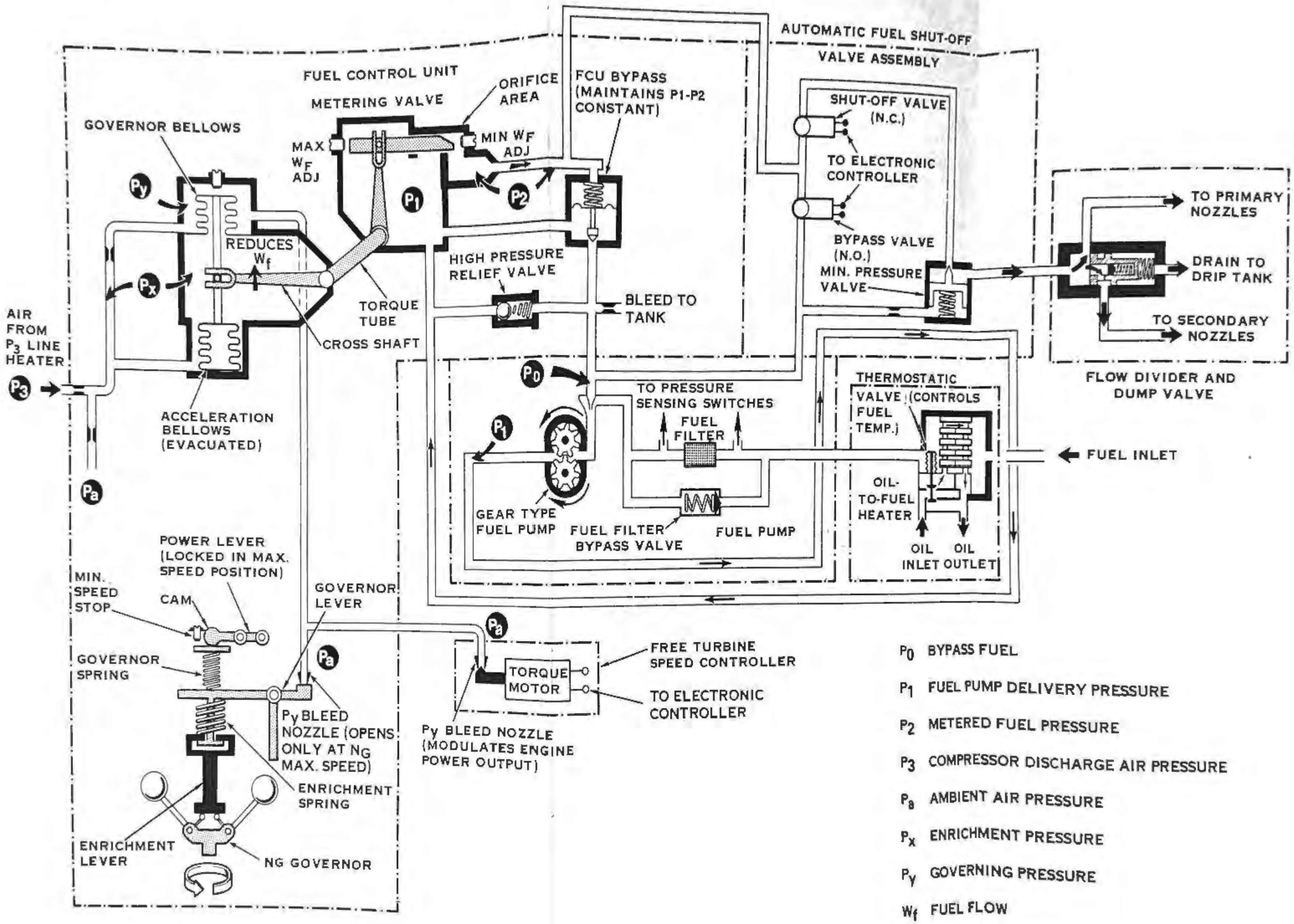
P_3 air from the engine is reduced by orifices to form P_x pressure and from P_x pressure to form P_y pressure. P_y pressure is applied to the outside of the governor bellows while P_x pressure is applied to the inside of the governor bellows and to the outside of the acceleration bellows. Any change in P_y will have more effect on the governor bellows than an equal change in P_x, due to

the difference in effective area. P_y and P_x vary with changing engine operating conditions. When both pressures increase simultaneously, the bellows cause the metering valve to move in an opening direction.

P_y pressure is normally controlled by the free turbine speed controller which controls the opening of the P_y bleed orifice. As the P_y bleed orifice opening increases, P_y force on the governor bellows is less thereby decreasing fuel flow. The APU Electronic Controller, through the free turbine speed controller, commands the gas generator to maintain the free turbine at a constant 33,000 rpm.

Fuel Control Leading Particulars

• Metered Fuel Flow	81 PPH minimum
• Metering Valve Differential Pressure	16 psid nominal
• Fuel Control rpm	0.167 N_g
• High Pressure Relief Valve Setting	950-1000 psig
• N_g Mechanical Topping	38,500 to 38,850 rpm



FUEL SYSTEM SCHEMATIC
FIGURE 1-12

P_0 BYPASS FUEL

P_1 FUEL PUMP DELIVERY PRESSURE

P_2 METERED FUEL PRESSURE

P_3 COMPRESSOR DISCHARGE AIR PRESSURE

P_a AMBIENT AIR PRESSURE

P_x ENRICHMENT PRESSURE

P_y GOVERNING PRESSURE

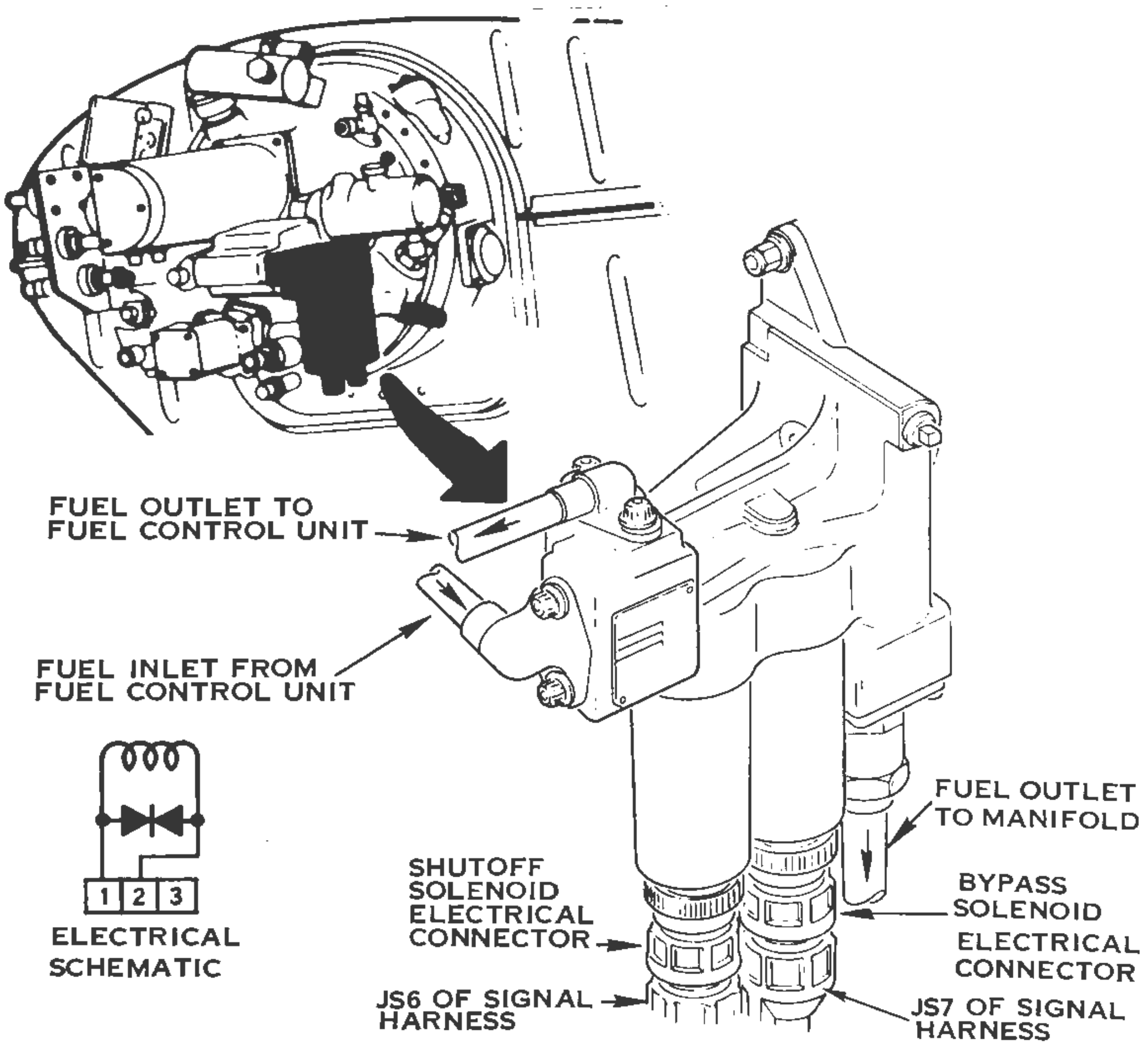
W_f FUEL FLOW

N_g ENGINE GAS GENERATOR SPEED

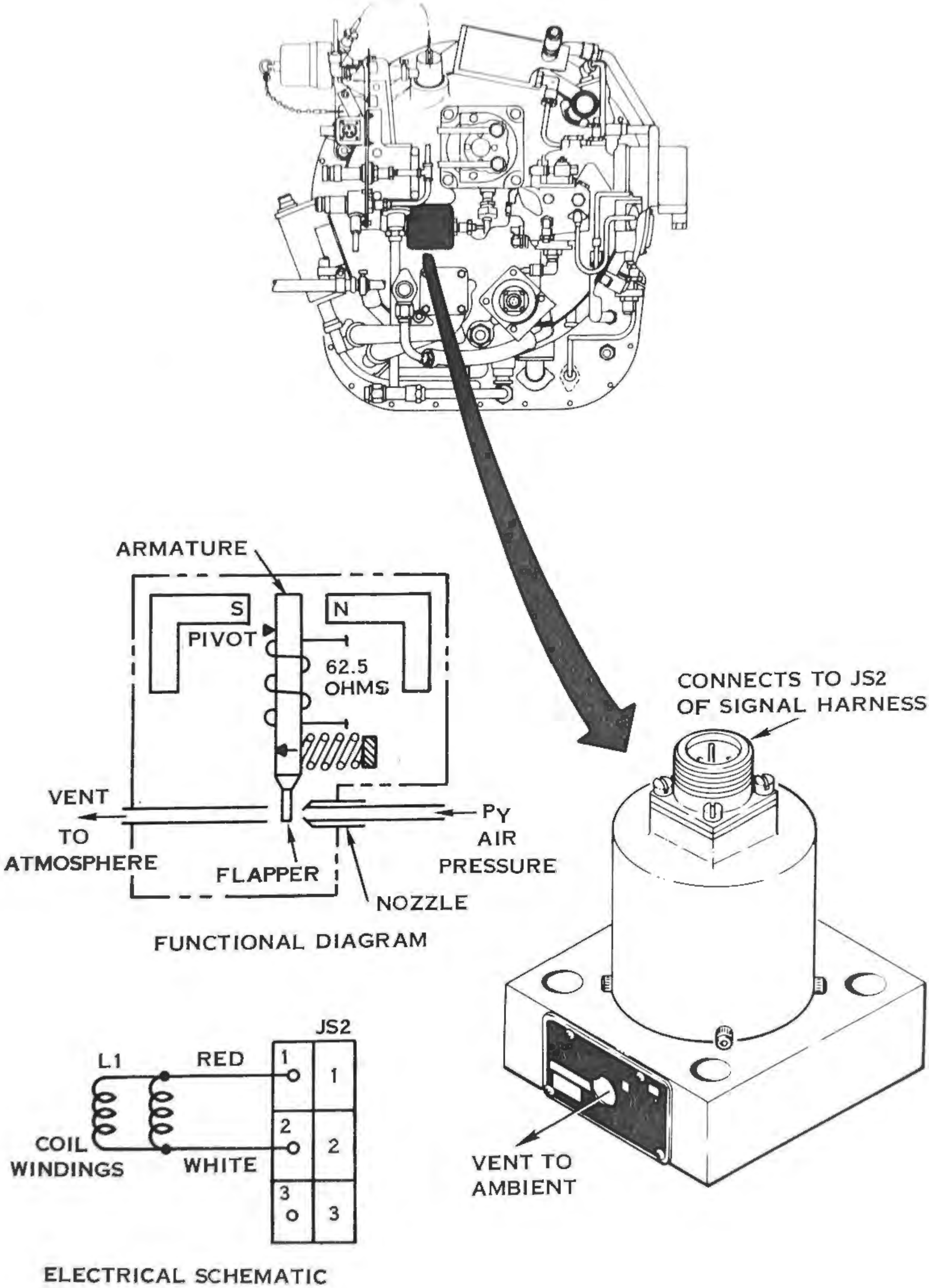
Automatic Fuel Shutoff Valve Assembly Description and Operation

The automatic fuel shutoff valve assembly (Figures 1-13 and 1-14) mounts on the power driven rotary fuel pump adjacent to the fuel control unit. It consists of a shutoff valve, a bypass valve, and a minimum pressure valve. The shutoff valve is a normally closed solenoid valve used to shut off fuel to the engine. The bypass valve is a normally open solenoid valve that bypasses fuel back to the fuel pump bypass inlet. The minimum pressure valve is spring loaded closed and opens only when fuel pressure is sufficient to overcome the spring force.

During the start sequence, both solenoids are energized simultaneously by 28 V dc from the APU Electronic Controller. This closes the bypass valve and opens the shutoff valve. Fuel supplied from the fuel control, as metered flow, passes through the shutoff valve to the minimum pressure valve which opens when fuel pressure reaches 50-70 psi above pump bypass inlet pressure. The open minimum pressure valve supplies fuel to the flow divider and dump valve. When the solenoids are de-energized the bypass valve opens allowing fuel to return to the pump bypass inlet.



AUTOMATIC FUEL SHUTOFF VALVE ASSEMBLY
FIGURE 1-14



FREE TURBINE SPEED CONTROLLER
FIGURE 1-15

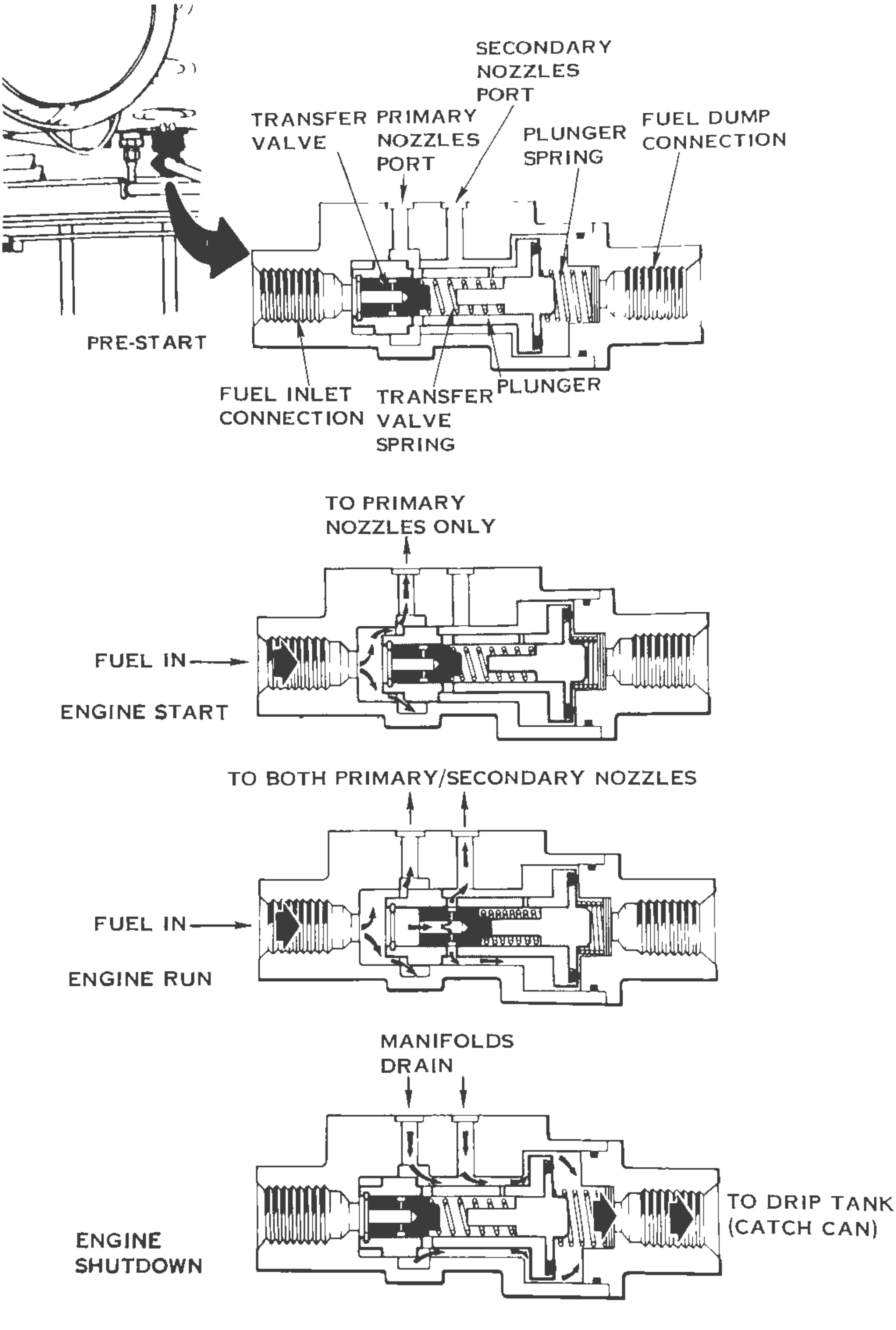
Free Turbine Speed Controller Description and Operation

The free turbine speed controller (Figure 1-15) is an electromagnetic torque motor and fluid amplifier mounted on the accessory gear case. The torque motor consists of a coil and magnet assembly and the fluid amplifier is a variable orifice consisting of a nozzle and a movable flapper.

The free turbine speed controller acts as the power lever for the engine under automatic control of the APU Electronic Controller. Current from the APU Electronic Controller exerts a torque, moving the flapper which in turn varies the P_y signal pressure of the fuel control unit. P_y pressure is the controlling parameter for metered fuel flow; increasing the P_y pressure will increase the metered fuel flow. Displacement of the flapper is proportional to the magnitude of the input signal.

Free Turbine Speed Controller Leading Particulars

• Normal Operating Range	0 to 150 ma
• Coil Resistance	62.5 ohms



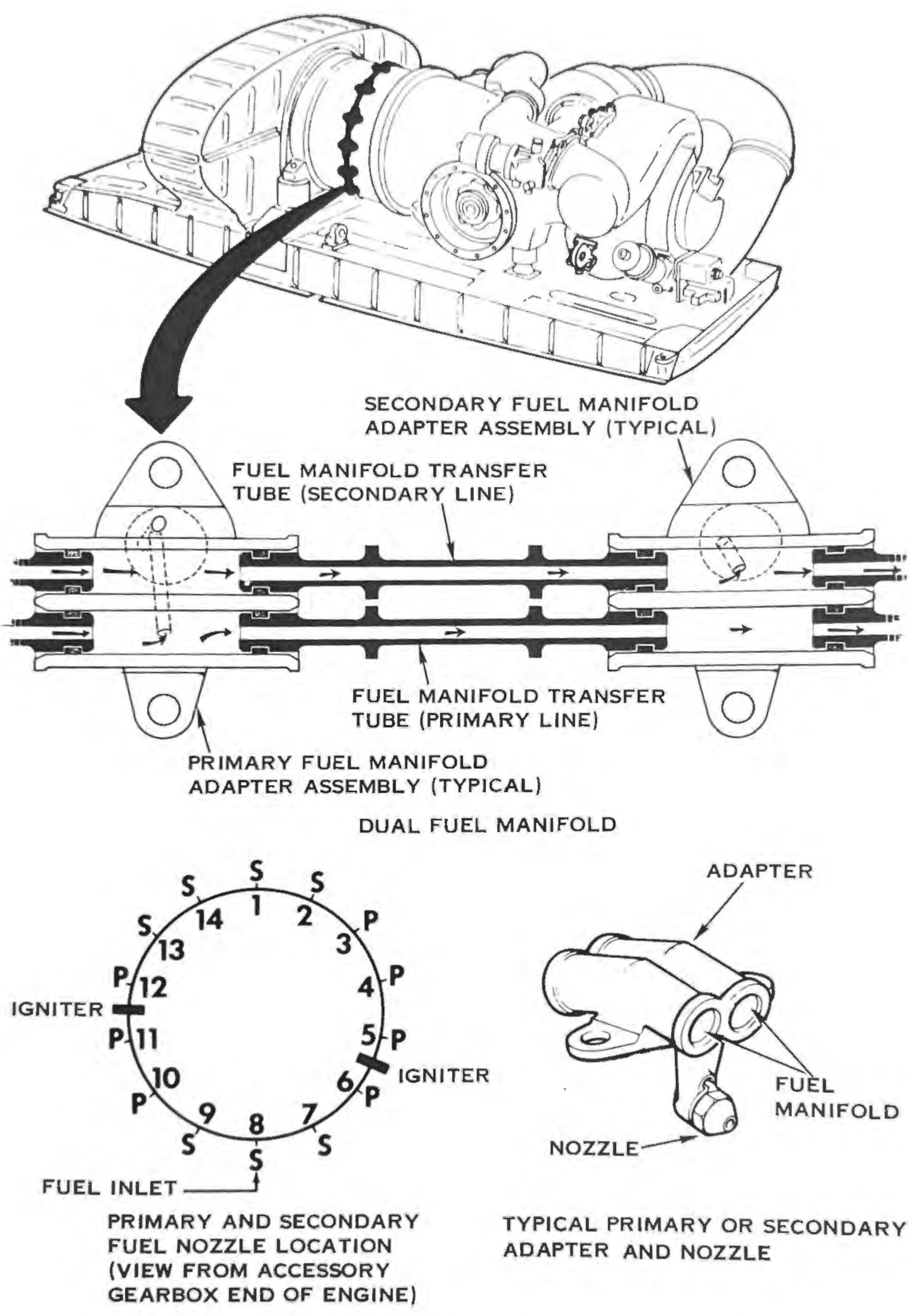
FLOW DIVIDER AND DUMP VALVE
FIGURE 1-16

Flow Divider and Dump Valve Description and Operation

The flow divider and dump valve (Figure 1-16) located at the bottom of the engine fuel manifold, consists of a spring-loaded plunger within a spring-loaded transfer valve. Both plunger and transfer valve oppose inlet fuel pressure.

The flow divider pressurizes the primary and secondary fuel manifolds as required for engine operation and provides a dump valve to drain the fuel manifolds at engine shutdown. During pre-start both plunger and transfer valve are spring loaded closed, porting primary and secondary manifolds to drain, and maintaining inlet fuel off. During engine start fuel inlet pressure drives the plunger from its seat and fuel enters the primary manifold. As flow and pressure increase, fuel pressure drives the transfer valve from its seat (19.5 psig) and fuel enters the secondary manifold.

The secondary manifold is closed when metered fuel pressure drops below 19.5 psig causing the transfer valve to close off the secondary manifold. As pressure decreases to 15 psig the dump valve allows the secondary manifold to drain. As pressure drops further the pluger seats, closing the fuel inlet and opening the primary manifold to drain.

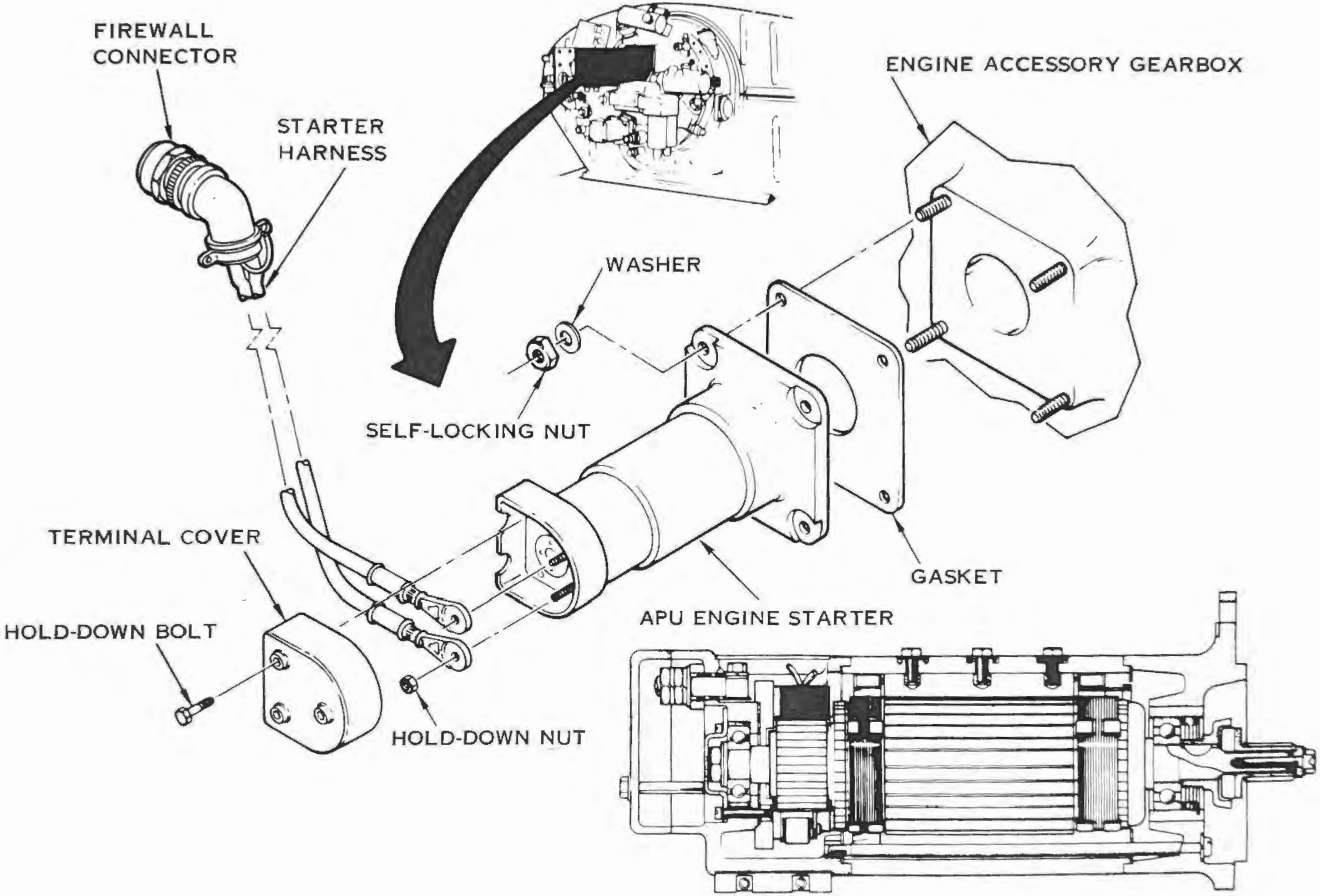


FUEL NOZZLE AND MANIFOLD ADAPTER ASSEMBLY
FIGURE 1-17

Fuel Nozzle and Manifold Adapter Assembly Description and Operation

There are fourteen nozzle assemblies spaced equally around the circumference of the gas generator case interconnected by short transfer tubes to form a dual fuel manifold (Figure 1-17). There are seven primary and seven secondary fuel nozzle and adapter assemblies. Each fuel adapter routes fuel only from respective primary or secondary manifold to a fuel nozzle. The fuel nozzle is a fixed orifice with a spring loaded swirl distributor.

Fuel supplied from the flow divider and dump valve to the manifolds is filtered by a strainer element before entering the spring loaded swirl distributor in the nozzle. Angularly arranged slots in the nozzle rapidly swirl the fuel as it enters the orifice through which the fuel is injected into the combustion chamber as a finely atomized spray.



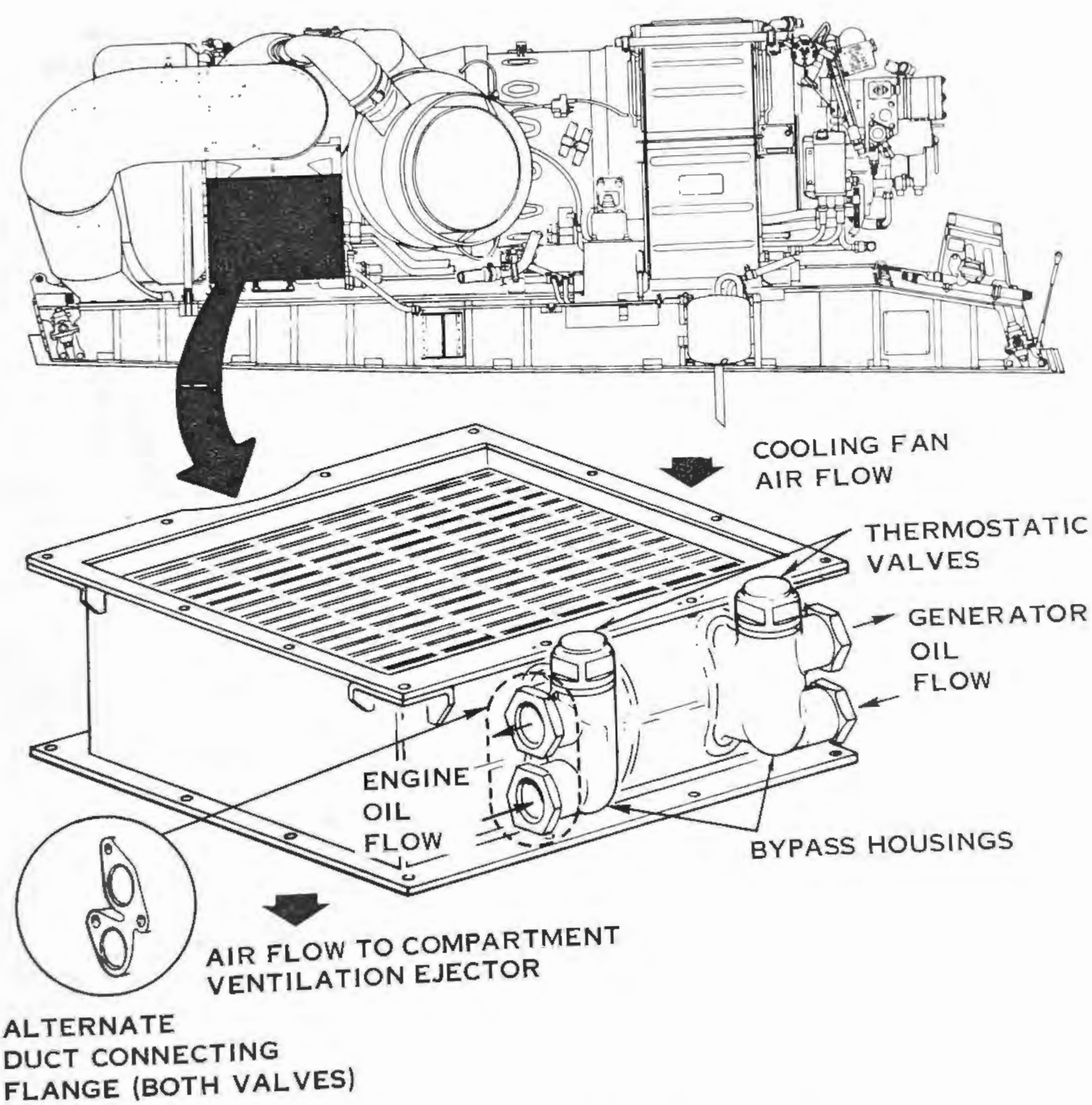
APU ENGINE STARTER AND STARTER HARNESS
FIGURE 1-18

APU Engine Starter and Starter Harness Description and Operation

The APU engine starter (Figure 1-18) is a 28 V dc motor which mounts on the accessory gearcase. The motor is a totally enclosed series-wound unit with four poles and brushes. A cover strap provides access to the brushes. The starter has the capability of turning the engine up to approximately 18% N_g.

A 28 V dc battery in the aircraft furnishes up to 600 amperes of current through an APU engine starter harness to drive the starter motor. The starter drive shaft is never disengaged from the engine but electrical power is removed by the APU Electronic Controller when the engine passes 55%N_g.

NOTE: The starter motor duty cycle is limited to no more than three consecutive APU engine starts or start attempts of 30 seconds duration (with a 30 second OFF period between starts). This should be followed by a minimum of one (1) hour cooling off period.



OIL-TO-AIR HEAT EXCHANGER
FIGURE 1-19

Oil-to-Air Heat Exchanger Description and Operation

The oil-to-air heat exchanger (Figure 1-19) is a rectangular unit bolted to the load hardware gearbox. Air from the cooling fan forces air through the heat exchanger. The heat exchanger is divided into two separate cores, one for the engine oil cooling and the other for the generator oil cooling. Each core has a separate thermostat which controls the oil bypass.

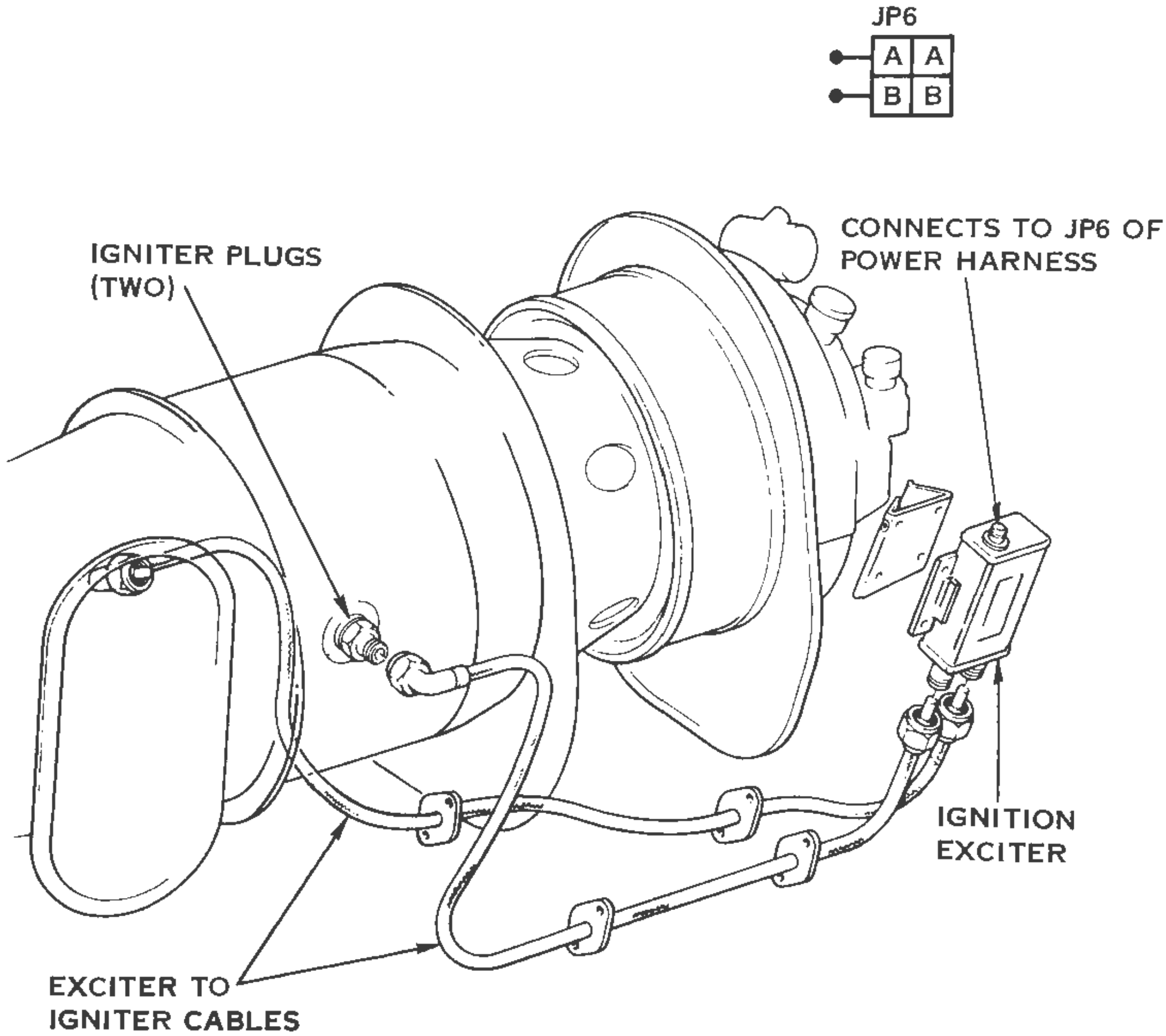
When cold oil enters either oil inlet port, it flows from the inlet port to the outlet port by way of a bypass. As the oil temperature increases the sensing element expands and seats against a bypass valve seat forcing the oil to flow through the core. Engine oil and generator oil enter respective core sections containing plate-type oil passages passing to the end manifold and back through other passages to the outlet port. Cooling air flows continually past the plate-type passage surfaces and cooling fins, absorbing heat from the oil. Each thermostat is spring loaded to act as a pressure relief valve allowing oil to bypass the core should core stoppage occur.

Oil-to-Air Heat Exchanger Leading Particulars

• Thermostat Bypass Closed.	176°F
• Relief Valve Opens.	60 psid

Ignition Exciter, Cable, and Plugs Description and Operation

The ignition exciter (Figure 1-20) is a sealed unit mounted on the accessory gear case containing electronic components encased in epoxy resin. The exciter provides electrical energy through exciter-to-igniter cables to the igniter plugs during engine starting only. One plug mounts at the 4 o'clock position and the other at the 9 o'clock position as viewed from the accessory gear case. The two igniter plugs (for redundancy) are used to provide a spark which ignites the fuel in the engine combustion chamber.



IGNITION EXCITER, CABLES, AND PLUGS
FIGURE 1-20

LOAD COMPRESSOR SYSTEM

LOAD COMPRESSOR SYSTEM

FREE TURBINE/LOAD HARDWARE SYSTEM

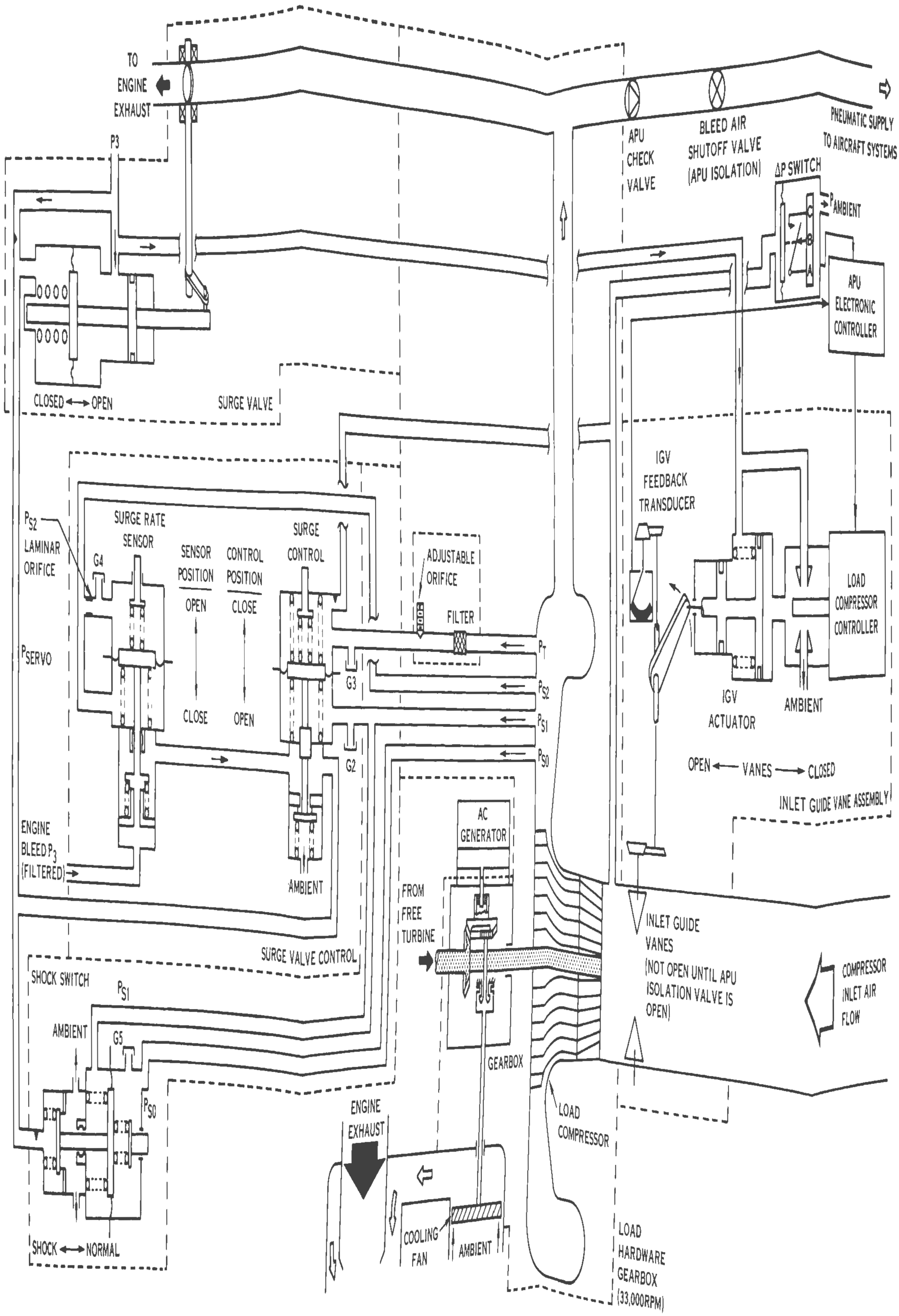
The free turbine/load hardware system (Figure 2-1) consists of a power distribution gearbox, load compressor, cooling fan, inlet guide vane assembly, IGV feedback transducer, load compressor controller, surge valve control, shock switch, surge valve, APU check valve and ΔP switch. The gearbox joins the engine free turbine shaft to the load compressor shaft and by gearing connects to the ac generator drive and cooling fan shaft. The inlet guide vane assembly at the load compressor inlet has the IGV feedback transducer and load compressor controller mounted to it near the IGV actuator. The shock switch and surge valve control mount on the load compressor housing with servo connection to the surge valve which mounts into a bypass duct that extends from the compressor outlet to the engine exhaust duct. The load compressor outlet connects to a pneumatic supply duct leading through the APU check valve and APU isolation valve to aircraft pneumatic systems.

The load hardware gearbox driven by the engine free turbine at a constant 33,000 rpm, provides a constant speed drive for the ac generator, pneumatic supply to aircraft systems, and cooling air for the APU compartment and components. Ambient air entering through a duct from the aircraft fuselage passes through inlet guide vanes to the load compressor and from the compressor the air flows to pneumatic systems through the APU check valve or to engine exhaust air through the surge valve. Ambient air entering the engine inlet door passes through the platform plenum to the cooling air fan and from the fan this air passes through the oil-to-air heat exchanger and vent ejector to ambient or through the engine cooling tube to the APU compartment or through an engine cooling annulus to the exhaust muffler.

Since the speed of the load compressor is constant, inlet guide vanes are positioned to vary the load compressor inlet air flow. The APU Electronic Controller receiving inputs from the Tt2 sensor and mode control switch on the APU CONTROL panel, sends current signals to the load compressor controller which deflect the controller flapper varying the P_3 bleed to ambient and regulating servo pressure supplied to the IGV actuator and thus altering inlet guide vane position. The IGV feedback transducer monitors guide vane position and sends signals to the APU Electronic Controller to balance the servo loop for any guide vane position. IGV position will normally be a function of Tt2 and load demands.

The demand from aircraft pneumatic systems will not match the load compressor output and since flow must be maintained to protect the load compressor from surge caused by either an inlet or outlet restriction, a surge control system is provided. Compressor diffuser static pressures sensed across diaphragms in the surge control, operate poppet valves that control servo pressure to the surge valve.

Increasing servo pressure drives the valve toward open. In conjunction with the surge control, a shock switch sensing compressor pressures, operates the surge valve toward closed in the event a supersonic shock wave is sensed in the outlet of the load compressor.



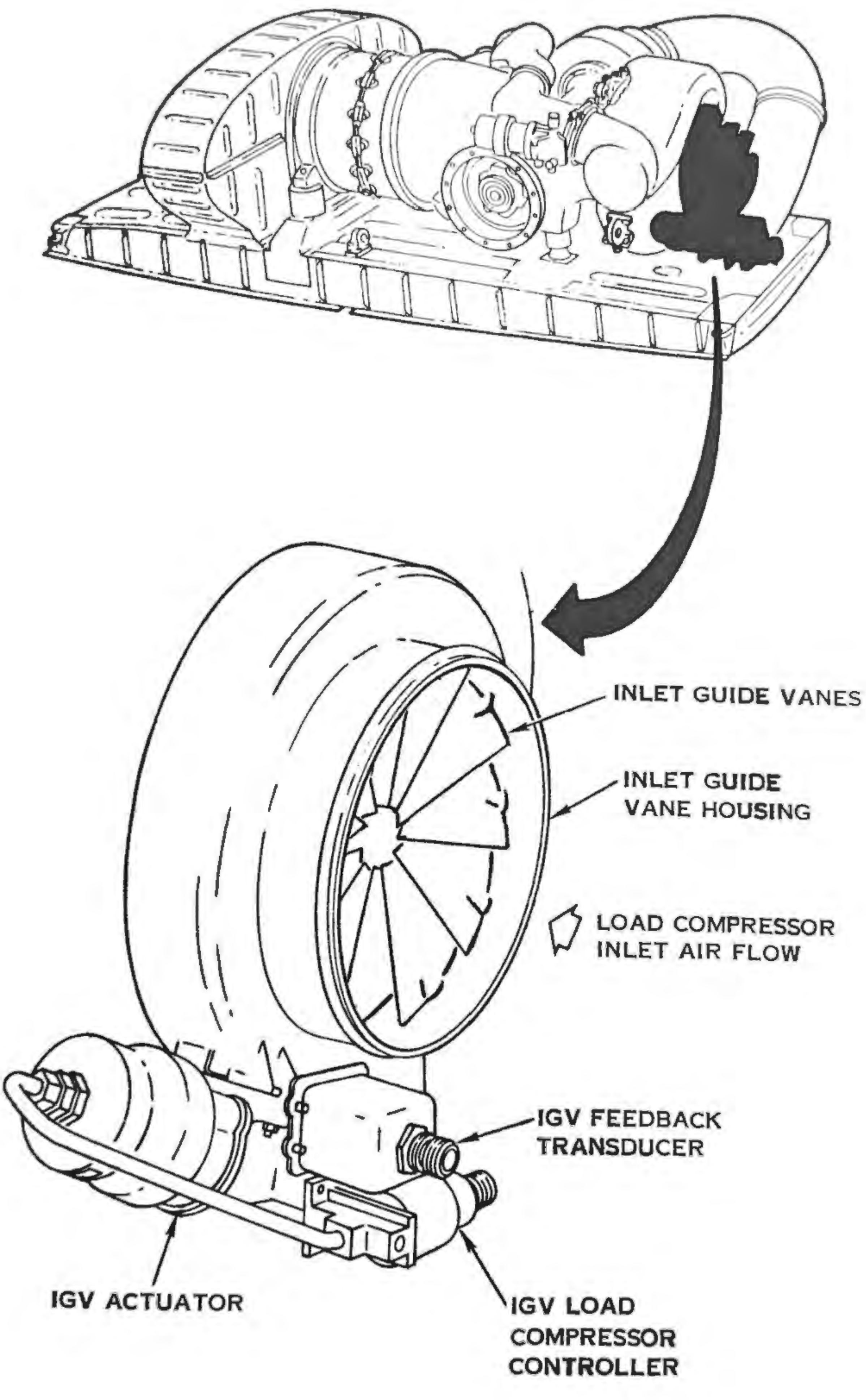
FREE TURBINE/LOAD HARDWARE SYSTEM SCHEMATIC
FIGURE 2-1

LOAD HARDWARE SYSTEM COMPONENTS

Inlet Guide Vane Assembly Description and Operation

The inlet guide vane (IGV) assembly (Figure 2-2) mounts on the load compressor housing on the aft end of the APU. In addition to the guide vanes and inlet housing, the IGV assembly includes an inlet guide vane feedback transducer, load compressor controller, and a pneumatically operated piston-type actuator.

The inlet guide vanes are never fully closed at any time. Pneumatic IGV servo pressure is supplied as P_3 pressure from the engine. The piston type actuator positions the guide vanes according to this pneumatic pressure as modulated by the load compressor controller. The inlet guide vanes are normally positioned according to the required schedule by the APU Electronic Controller which signals the load compressor controller to establish the proper amount of P_3 servo supply. As the inlet guide vanes move, a linkage system drives the potentiometer on the IGV feedback transducer which is biased as a voltage divider by the APU Electronic Controller, to signal that a new IGV null point is required (feedback loop).



INLET GUIDE VANE ASSEMBLY
FIGURE 2-2

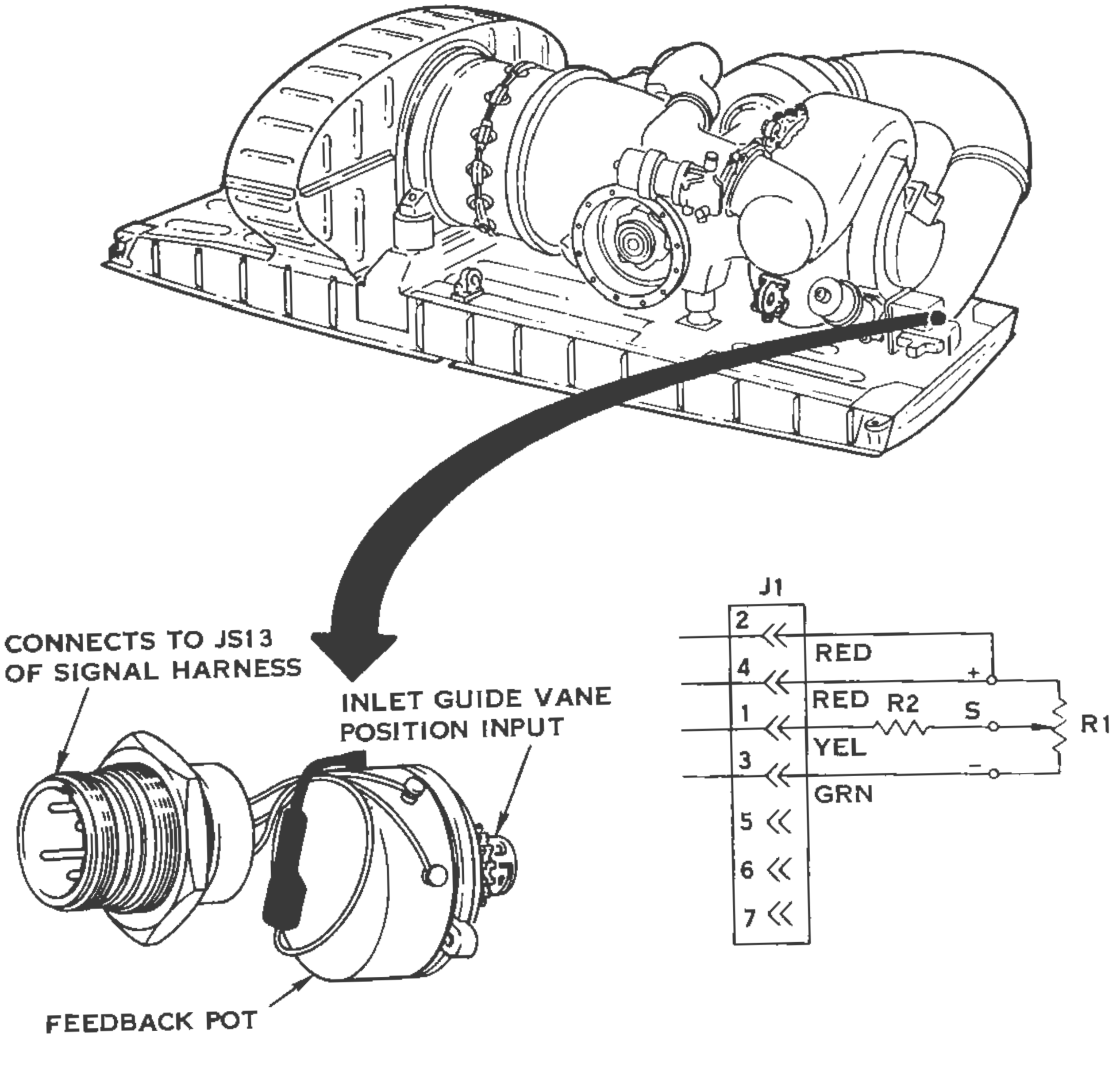
IGV Feedback Transducer Description and Operation

The IGV feedback transducer (Figure 2-3) mounts on the inlet guide vane assembly and consists of a variable resistor, a fixed current-limiting resistor (potentiometer) and an electrical connector within a protective cover.

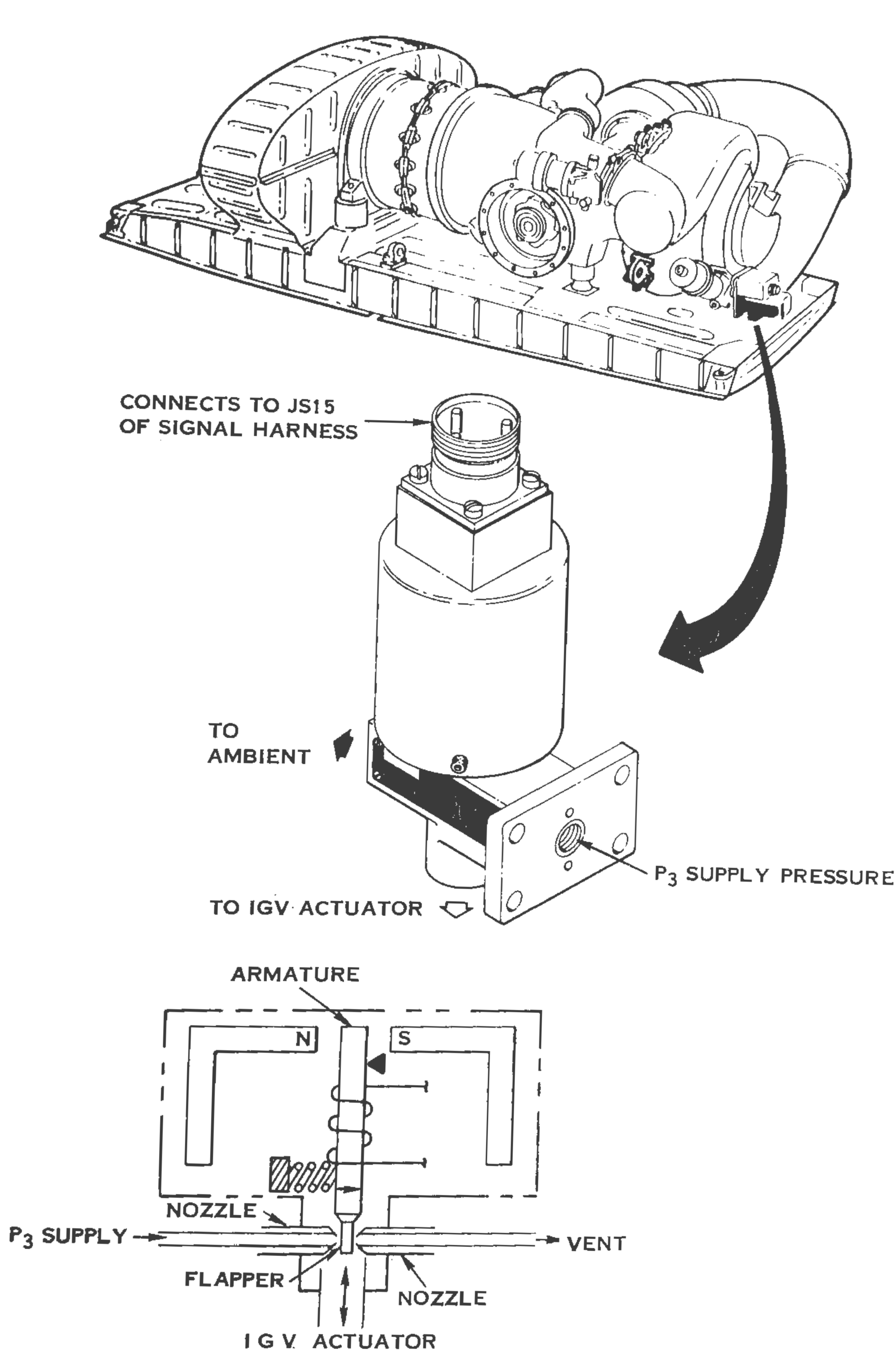
The variable resistor is a rotary precision potentiometer which converts the mechanical position of the inlet guide vanes into an electrical voltage. The signal is fed via the signal harness and aircraft wiring to the APU Electronic Controller. Voltage of approximately 2.3 volts is an indication of closed guide vanes and 8 V dc is an indication of full open guide vane position.

IGV Feedback Transducer Leading Particulars

- R1 Resistance 10 K $\pm$ 1 K ohms
- R2 Resistance 499 $\pm$ 5 ohms
- Connector MS 24265R14T7PN



IGV FEEDBACK TRANSDUCER
FIGURE 2-3



LOAD COMPRESSOR CONTROLLER
FIGURE 2-4

Load Compressor Controller Description and Operation

The load compressor controller (Figure 2-4) mounts on the inlet guide vane assembly and consists of an electro-magnetic torque motor and fluid amplifier. The torque motor consists of a coil magnet assembly and the fluid amplifier contains two nozzles which in conjunction with a movable flapper form two variable orifices.

Variations in the direct current electrical input from the APU Electronic Controller provide signals to the torque motor to position the flapper. Flapper position is proportional to the amount of current flow. A decrease in current moves the flapper against the ambient bleed orifice which provides higher pressure to the IGV actuator and moves the vanes toward the open position. An increase in current moves the flapper toward the servo supply orifice decreasing IGV actuator servo pressure and moving the vanes toward the closed position. The flapper is spring loaded toward the ambient bleed orifice, so that loss of electrical power will cause the inlet guide vanes to go full open.

Load Compressor Controller Leading Particulars

• Normal Operating Full Current	170 to 200 ma
• Coil Resistance	33 to 39 ohms at 70°F
• Lead Wires to Body Resistance	200 megohms minimum
• Connector	MS24264R12T-3PNX

Load Hardware Gearbox Description

The load hardware gearbox (Figure 2-5) consists of a gearbox, load compressor, and cooling air fan. The gearbox secured to the engine housing, serves as a power distribution source to drive the cooling air fan, and electric ac generator.

The load compressor is a centrifugal air compressor mounted directly on the aft end of the main gearbox drive shaft. The compressor inlet supports the inlet guide vane assembly. A bypass port at the compressor outlet provides mounting for the surge valve.

The load compressor housing diffuser forms a venturi chamber which has four pressure pickoffs; P_{S0}, P_{S1}, P_{S2} and P_T. The venturi chamber is a divergent duct to subsonic flows and there is a progressive pressure rise from P_{S0} to P_T. If the flow becomes supersonic the venturi chamber acts as a convergent duct and there is a progressive pressure loss from P_{S0} to P_T.

Later models of the load compressor have an adjustable orifice attached to the compressor housing over the P_T port which adjusts the characteristics of the load compressor to be compatible with any surge valve control. This orifice adjustment was initially set during manufacture and finally set during APU testing. This is not normally a field adjustment.

The cooling air fan is a seven-bladed, mixed-flow type axial fan encased in a molded plastic housing which attaches directly to the gearbox. The gearbox also provides a mounting pad and adapter for attachment of the ac generator.

Load Hardware Gearbox Operation

Rotational power is transmitted from the free turbine shaft through a quill shaft to the load compressor. Bevel gears, lubricated by a spray bar, split the torque path so that the free turbine drives to the load compressor and ac generator simultaneously. The cooling air fan is spur driven from the generator drive gear and the cooling air fan shaft incorporates a reverse rotation-locking clutch.

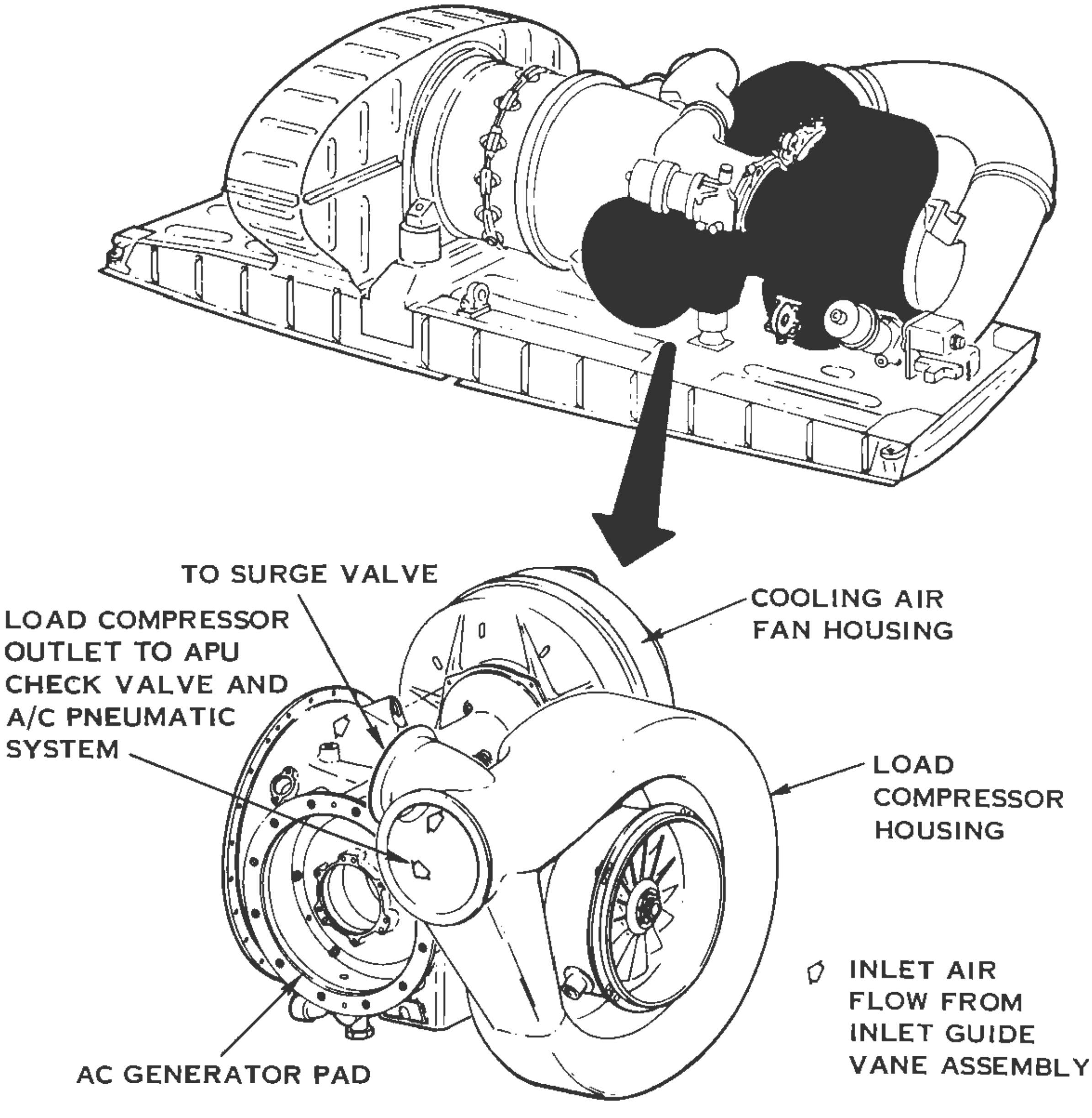
The load compressor draws air through the inlet guide vane assembly, compresses the air and supplies this air to aircraft pneumatic system supply ducts and to the APU surge valve.

The cooling air fan (Figure 2-6) provides air for APU compartment ventilation, engine exhaust shroud cooling, and oil-to-air heat exchanger cooling to cool generator and engine oils.

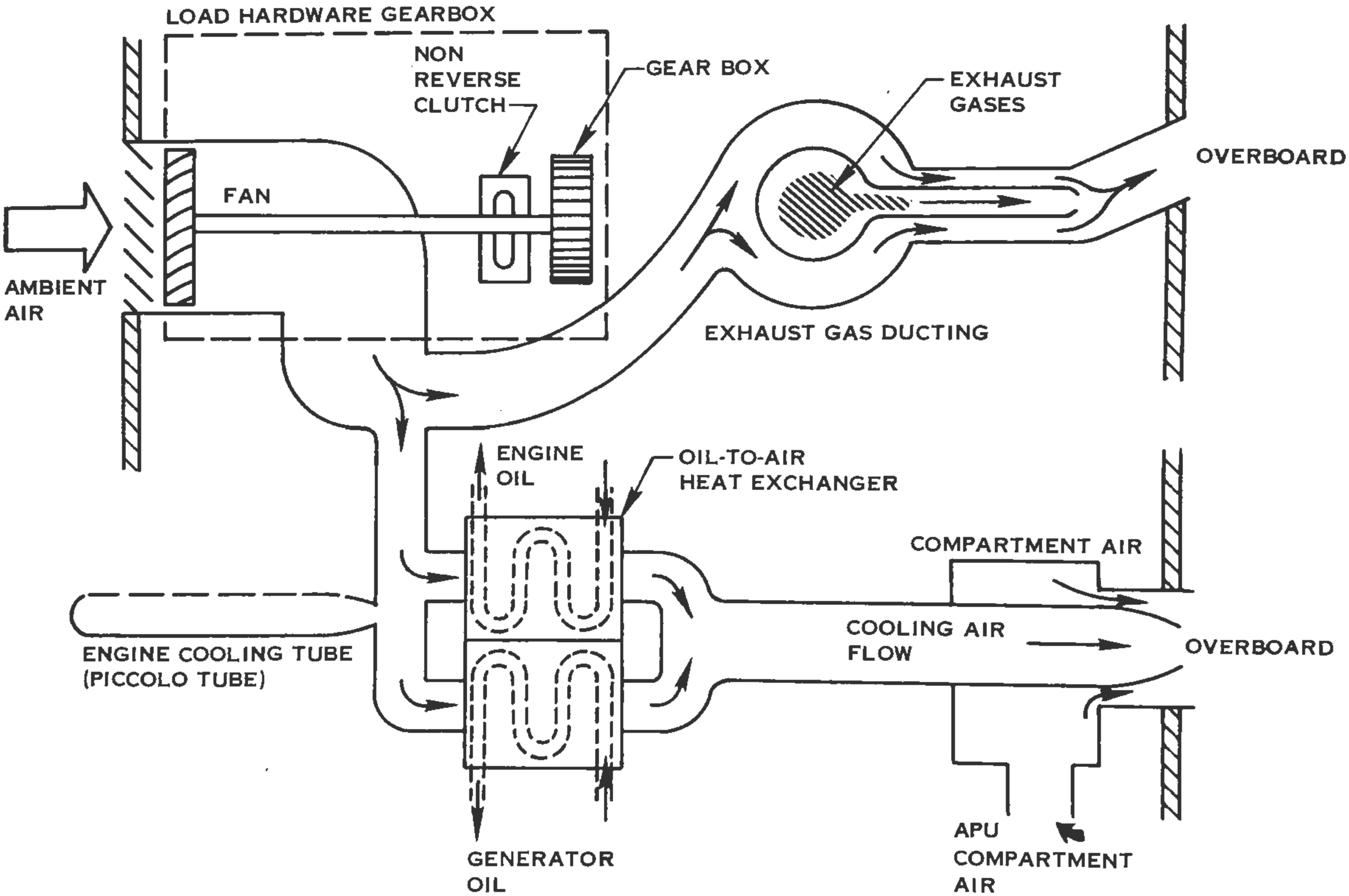
Load Hardware Gearbox Leading Particulars

- Gearbox Input 33,000 rpm, constant

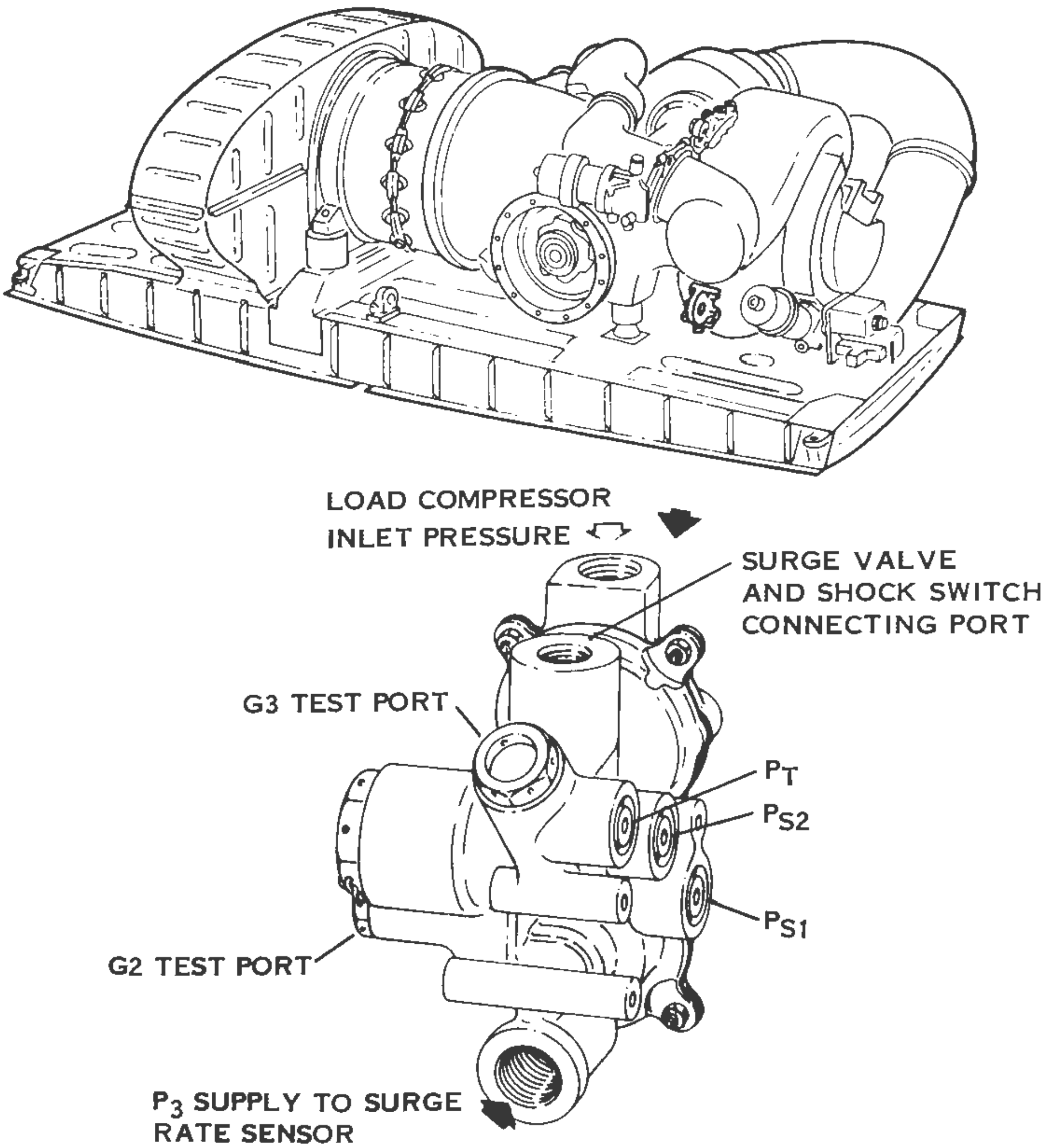
• Load Compressor	33,000 rpm, constant approximately 600 shp normal mode seal level (standard day)
• Cooling Air Fan	32,869 rpm, constant approximately 20 shp
• Electric Generator Drive Speed	12,000 rpm, constant approximately 70 shp/45 kw



LOAD HARDWARE GEARBOX
FIGURE 2-5



APU COOLING AIR FAN FLOW
FIGURE 2-6



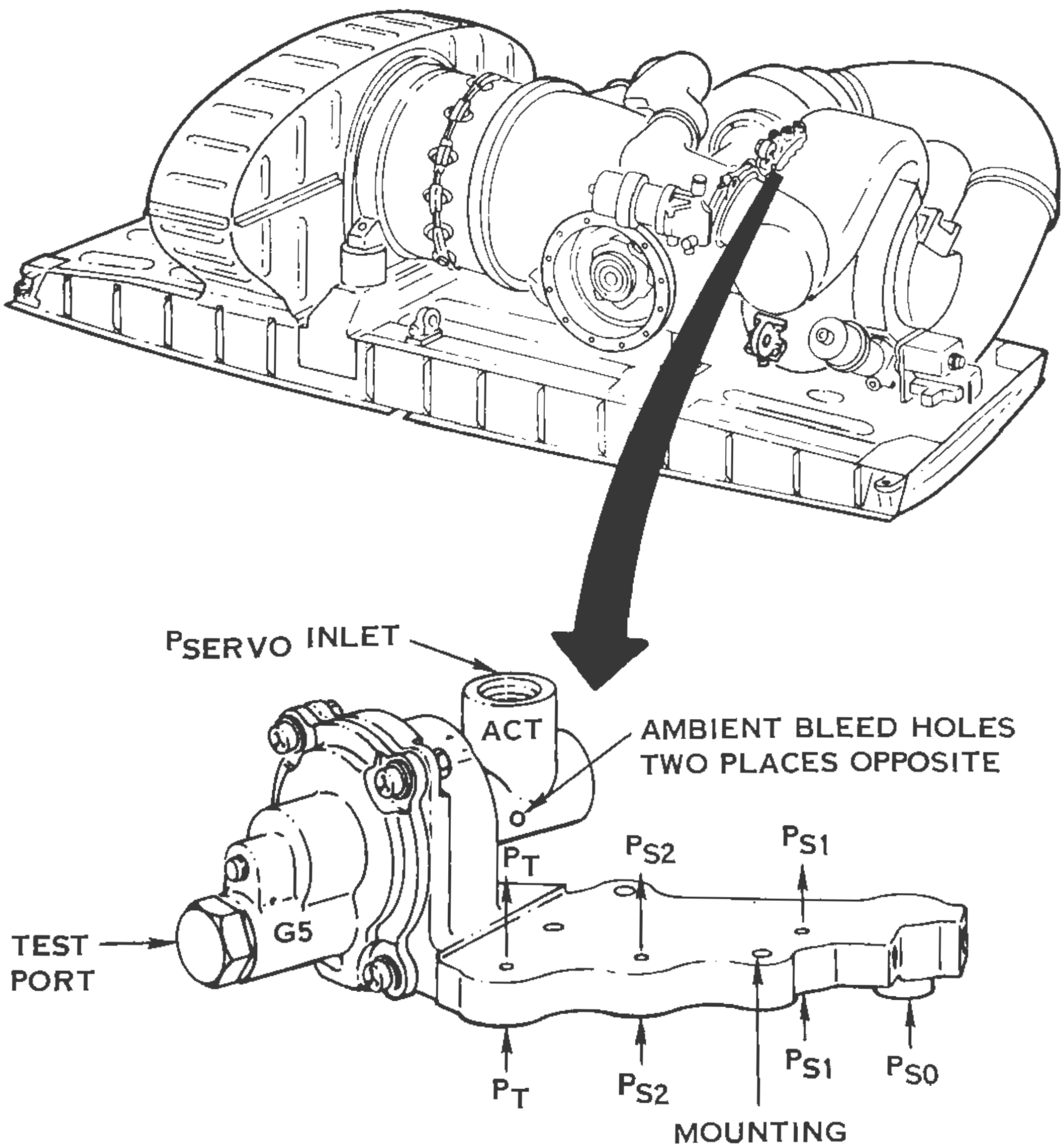
SURGE VALVE CONTROL
FIGURE 2-7

Surge Valve Control Description

The surge valve control (Figure 2-7) consists of two diaphragm operated poppet valves with internal passageways that lead to P_{S1}, P_{S2} and P_T pressure taps on the load compressor. The P_{S1} and P_T passageways lead to a surge control and the P_{S2} passageways lead to a surge rate sensor.

The surge control monitors P_{S1} and P_T load compressor pressures to regulate servo pressure supplied to the surge valve. The compressor pressures combined with a spring force are compared across a diaphragm which operates a poppet valve over an ambient bleed orifice. As load compressor discharge flow increases the differential pressure increases causing the poppet valve to move away from its seat, thus lowering surge valve servo pressure and driving the surge valve toward closed. As the surge valve closes, it slows down flow, lowering the differential pressure and balancing the servo loop. The flow continually biases the surge control to obtain correct surge valve opening for any aircraft pneumatic system load.

The surge rate sensor monitors P_{S2} pressures on both sides of a diaphragm which operates a poppet valve over a direct P_3 surge valve servo pressure source. P_{S2} pressure must pass through a laminar orifice to reach one side of the diaphragm and this orifice slows the effect of pressure changes. A fast increase in P_{S2} pressure drives the poppet from its seat admitting P_3 air directly to the surge valve causing the surge valve to open rapidly. As the pressure through the laminar orifice increases, the poppet valve reseats closing off the P_3 servo and returning the surge valve to normal surge control scheduling. The surge rate sensor provides surge valve reaction to rapid increases in back pressure.

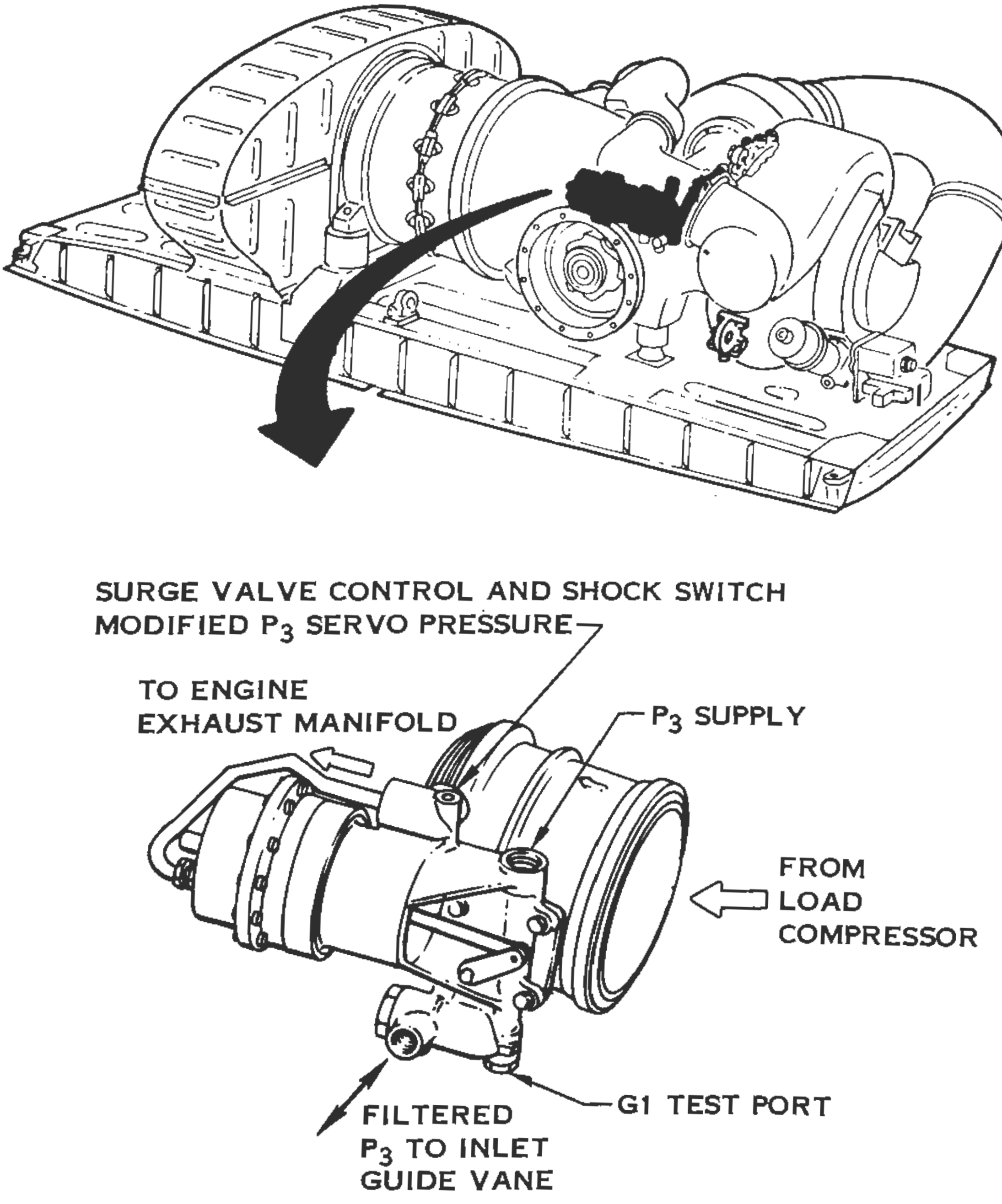


SHOCK SWITCH
FIGURE 2-8

Shock Switch Description and Operation

The shock switch (Figure 2-8) is a pneumatic, diaphragm-sensing poppet valve control positioned between the load compressor housing and the surge valve control. The shock switch has a single external port to which surge valve servo pressure is routed. Drilled passages through the mounting flange align with P_{S1}, P_{S2}, and P_T venturi pickoffs, and a transfer tube connects to the P_{S0} venturi pickoff. The P_{S1}, P_{S2} and P_T passages pass through to the surge valve control. The P_{S1} and P_{S0} passages lead to the shock switch sensing chamber.

When the shock switch senses negative pressure from P_{S1} to P_{S0} the diaphragm opens a poppet that dumps surge valve servo pressure to ambient. By dumping surge valve servo pressure to ambient, the shock switch overrides the surge valve control driving the surge valve toward full closed.

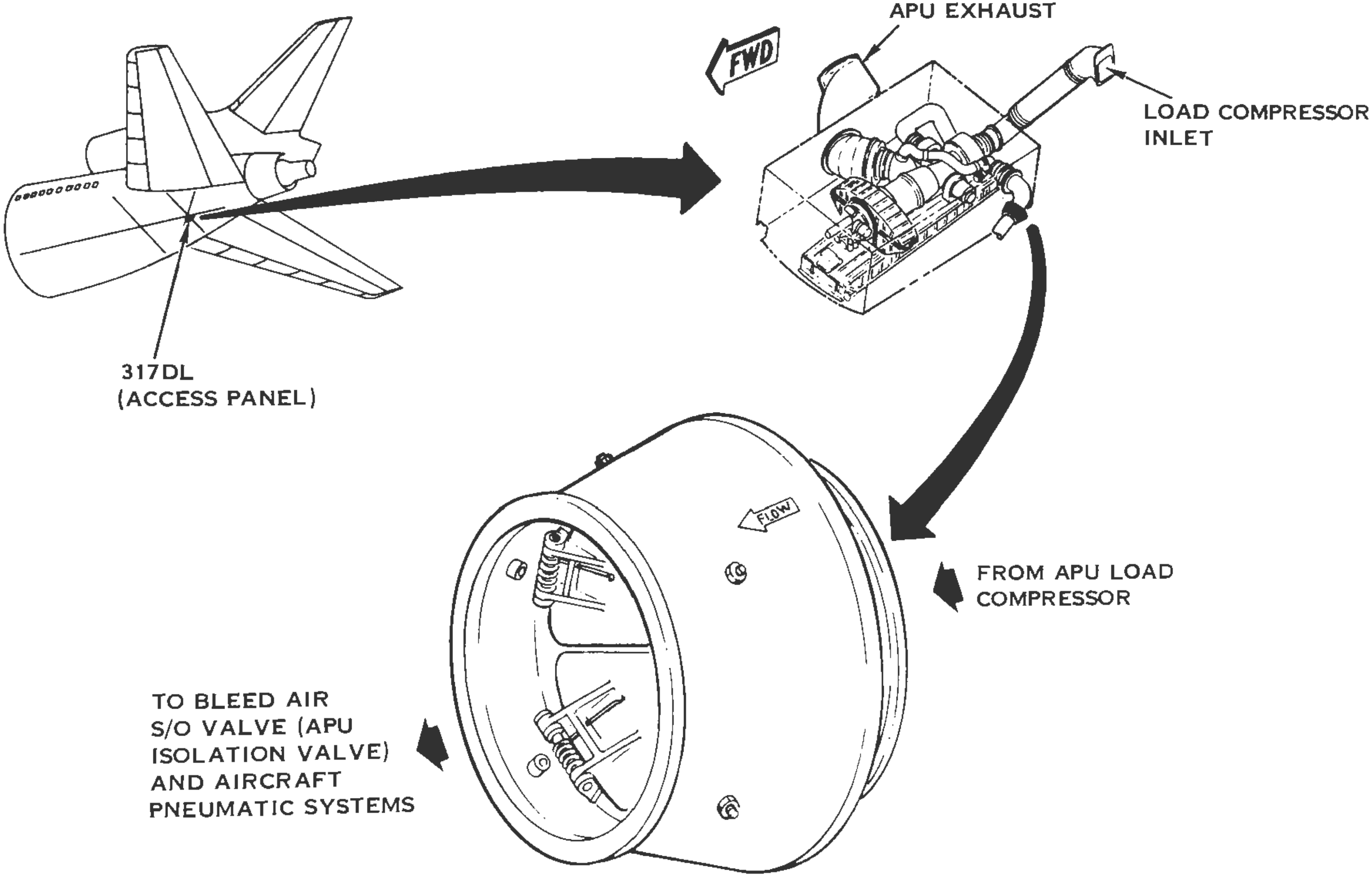


SURGE VALVE
FIGURE 2-9

Surge Valve Description and Operation

The surge valve (Figure 2-9) mounts to the bypass outlet of the load compressor housing and consists of a 5.75-inch diameter butterfly valve mechanically linked to a pneumatic actuator containing a piston and a spring loaded diaphragm assembly. The piston is spring loaded in the open position. The filtered P_3 air is supplied to oppose the spring loaded diaphragm to position the valve toward the proper position.

The surge valve control normally regulates the surge valve position. APU engine compressor bleed air, P_3, provides the force to hold the actuator in any position from 0-100% of actuator stroke. A modified P_3 developed by a fixed orifice in the surge valve assembly and a variable orifice in the surge valve control is sent to the spring loaded side of the surge valve. Filtered P_3 pressure is applied directly to the other side of the diaphragm. When the surge valve control senses decreases in aircraft pneumatic system demand, it moves its control poppet toward closed building up modified P_3 servo and driving the valve toward open. If the shock switch actuates, the modified P_3 servo pressure is dumped moving the surge valve toward closed. The open surge valve allows compressor output to flow into the engine exhaust.



APU CHECK VALVE
FIGURE 2-10

APU Check Valve Description and Operation

The APU check valve (Figure 2-10) assembly is a six petaled, flapper type valve installed in the APU outlet duct that supplies aircraft pneumatic systems. The APU check valve prevents reverse flow of aircraft system air toward the load compressor.

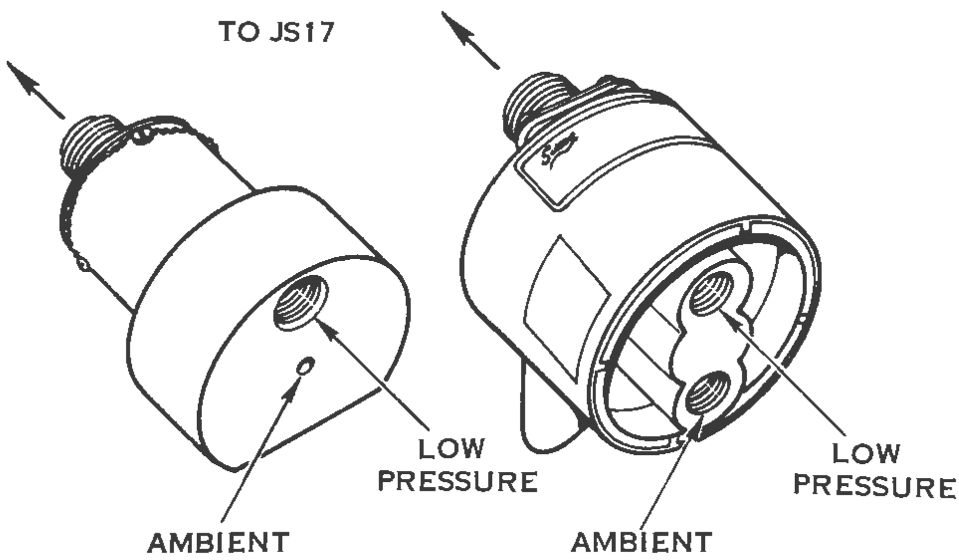
ΔP Switch Description and Operation

The ΔP switch (Figure 2-11) is a protective device to shutdown the APU in the event of load compressor inlet duct blockage. When blockage (such as ice) results in low inlet pressure, the ΔP switch closes a circuit with supplies 28 VDC through the MAX select relay to the inlet flow relay (4999-K13) which turns on the fault shutdown INLET FLOW light on the APU control panel and de-energizes the APU stop relay (4961-K1) causing a normal stop cycle (via the APU Electronic Controller).

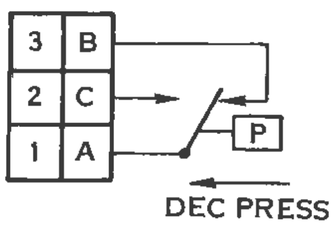
This fault shutdown mode is disabled when the IGV max select relay is energized by main engine start or placing the MODE SELECT switch in the MAX mode position.

ΔP switch leading particulars

- Actuates at - 4.7 ± 0.2 psig (for switches mfd by Consolidated Controls Corp).
  or
  -5.0 ± 0.3 psig (for switches mfd by Sierra Engineering Corp).



NOTE:
EITHER SWITCH SHOWN MAY BE USED WITH THE APU



ΔP SWITCH
FIGURE 2-11

CONTROLS AND INDICATOR INTERFACES

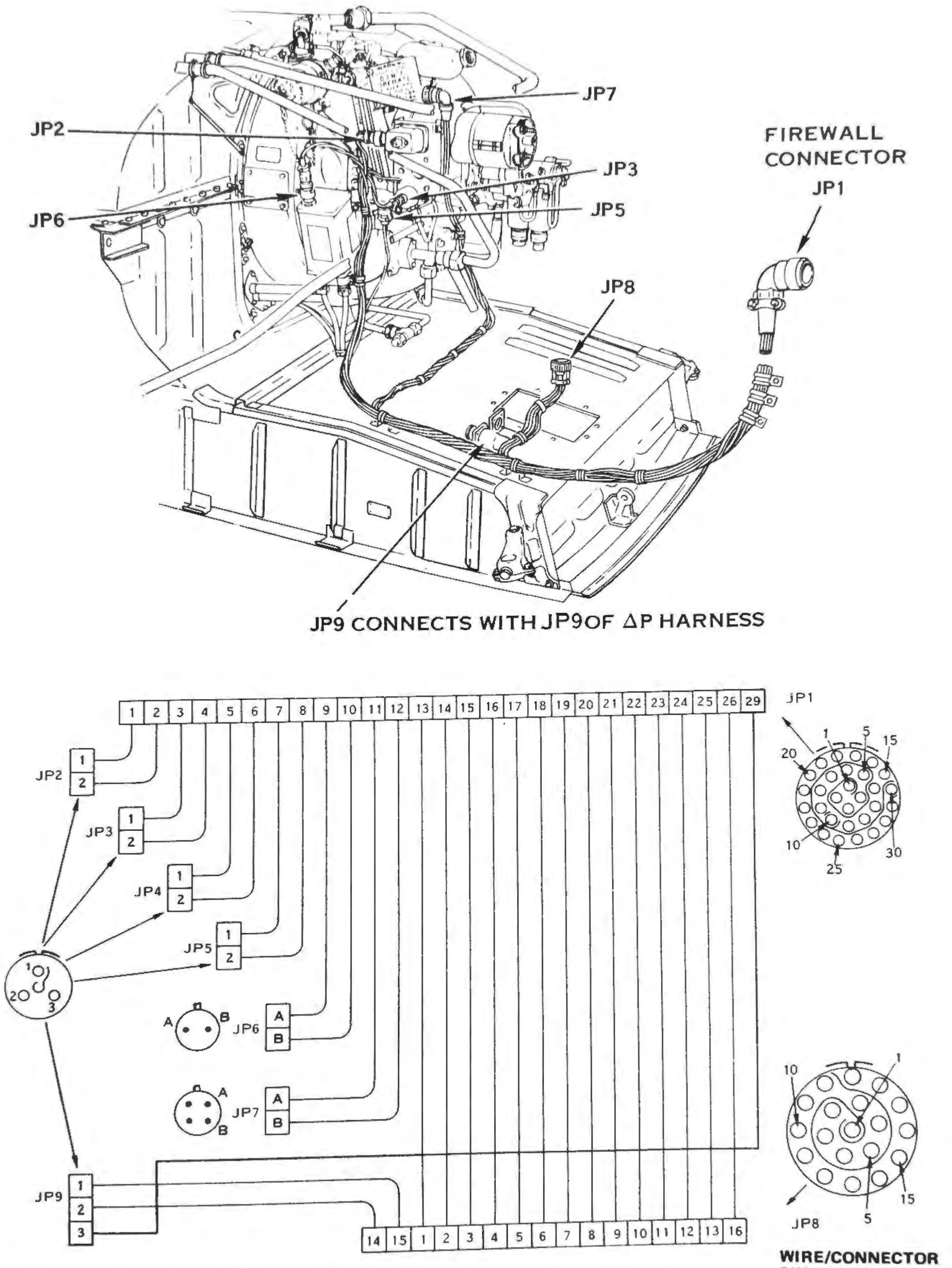
CONTROLS AND INDICATOR INTERFACES

GENERAL

This section covers detailed description, operation and leading particulars on those components of the APU and APU engine that are not directly interrelated and therefore do not lend themselves to a particular system. Additional controls and indicators that are interrelated to a given system are covered in their respective sections.

In addition to the power and signal harnosses, components that provide measurement of the following APU operating conditions are detailed in this section:

• APU Operating Time	Elapsed Time Indicator
• AC Generator Operation	Current Transformer
• N_g Speed	Gas Generator Tachometer
• N_f Speed	Free Turbine Speed Sensor
• Engine Temperature	T1, T3, T7 Temperature Sensing Harness
• Engine Inlet Air Temperature	Inlet Temperature Sensor
• Load Compressor Inlet Pressure Differential	ΔP Switch



NOTE:
FOR EASE OF REFERENCE, CONNECTORS ARE NOT SHOWN IN TRUE RELATIONSHIP TO HARNESS BRANCHES.

POWER HARNESS
FIGURE 3-1

CONTROL AND INDICATOR INTERFACE COMPONENTS

Power Harness Description and Operation

The power harness (Figure 3-1) consists of eight electrical bundles, a firewall connector and their respective electrical connectors. Aircraft circuits connect the power harness to flight station warning indicators and switches in the aircraft relay logic independent of the APU Electronic Controller. The power harness connectors are identified by designator numbers which appear on the sleeving behind each connector. The power harness interconnects through the ΔP harness to the signal harness.

NOTE: See power harness leading particulars for the component nomenclature corresponding to the connector designation.

A wire/connector pin arrangement is provided for ease of identification.

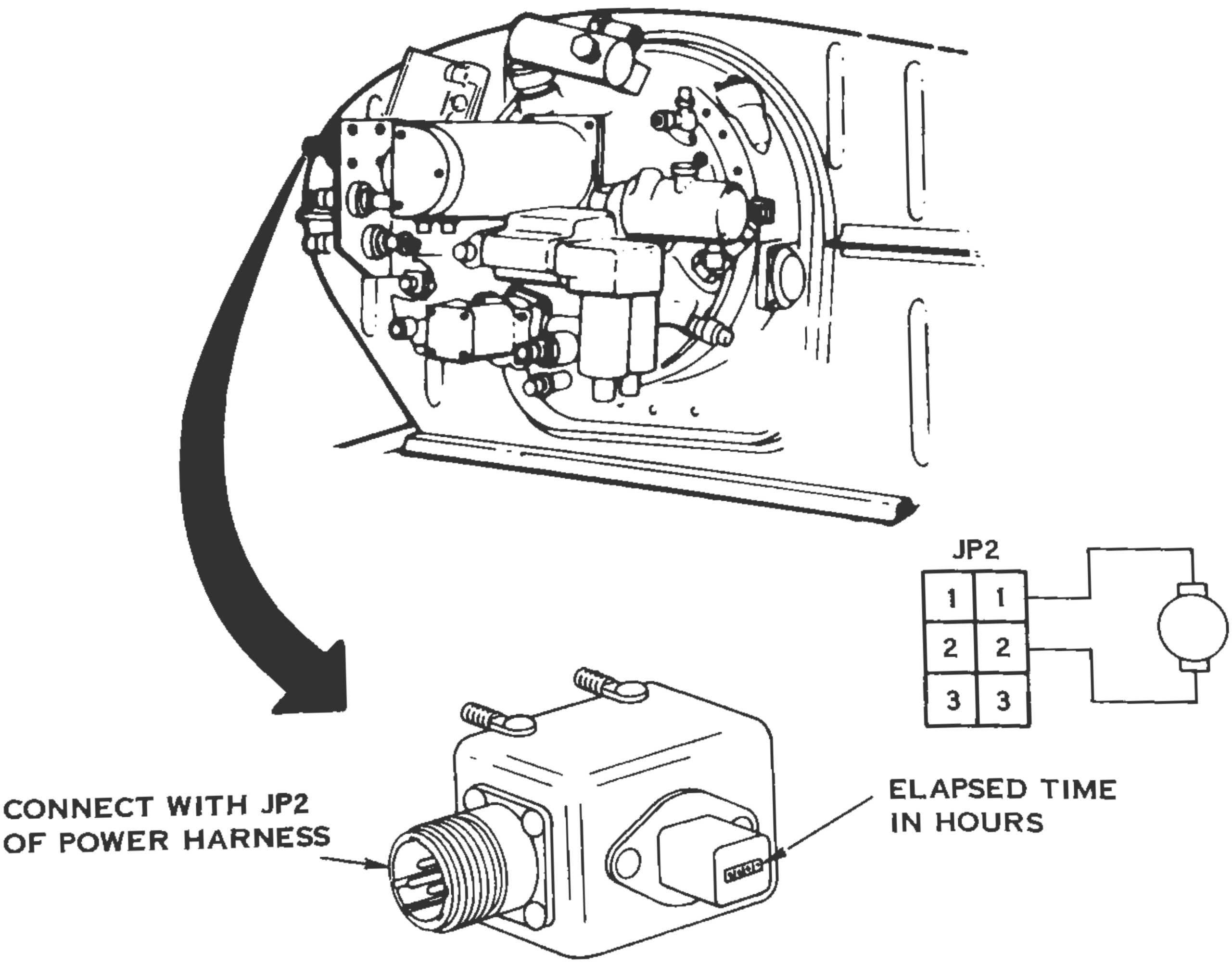
Power Harness Leading Particulars

APU Component Name	Connector Designation	Connector Part Number
• Firewall Connector	JP1	FPK112430PT (V49367)
• Elapsed Time Indicator	JP2	MS24266R12T3S7X or MS24266R12T3S7
• Clogged Fuel Filter	JP3	MS24266R12T3S9
• Low Fuel Pressure Switch	JP4	MS24266R12T3S10
• Float Switch (low oil quantity)	JP5	MS24266R12T3S6
• Ignition Exciter	JP6	MS3108R12S3S
• P3 Line Heater	JP7	MS3108R14S2S
• Engine Inlet Door Actuator	JP8	MS24266R22T19SN
• ΔP Harness Interconnect	JP9	MS24266R12T3PN

Insulation resistance between wires and between each wire and its connector case must be 100 megohms minimum.

Elapsed Time Indicator Description and Operation

The elapsed time indicator (Figure 3-2) is an electric timer that mounts on the engine accessory gear box. The elapsed time indicator is powered by aircraft supplied 115 V ac, 400 Hz carried to the indicator by the power harness. The indicator furnishes a continuous digital reading for zero to 9,999 hours in one hour increments.



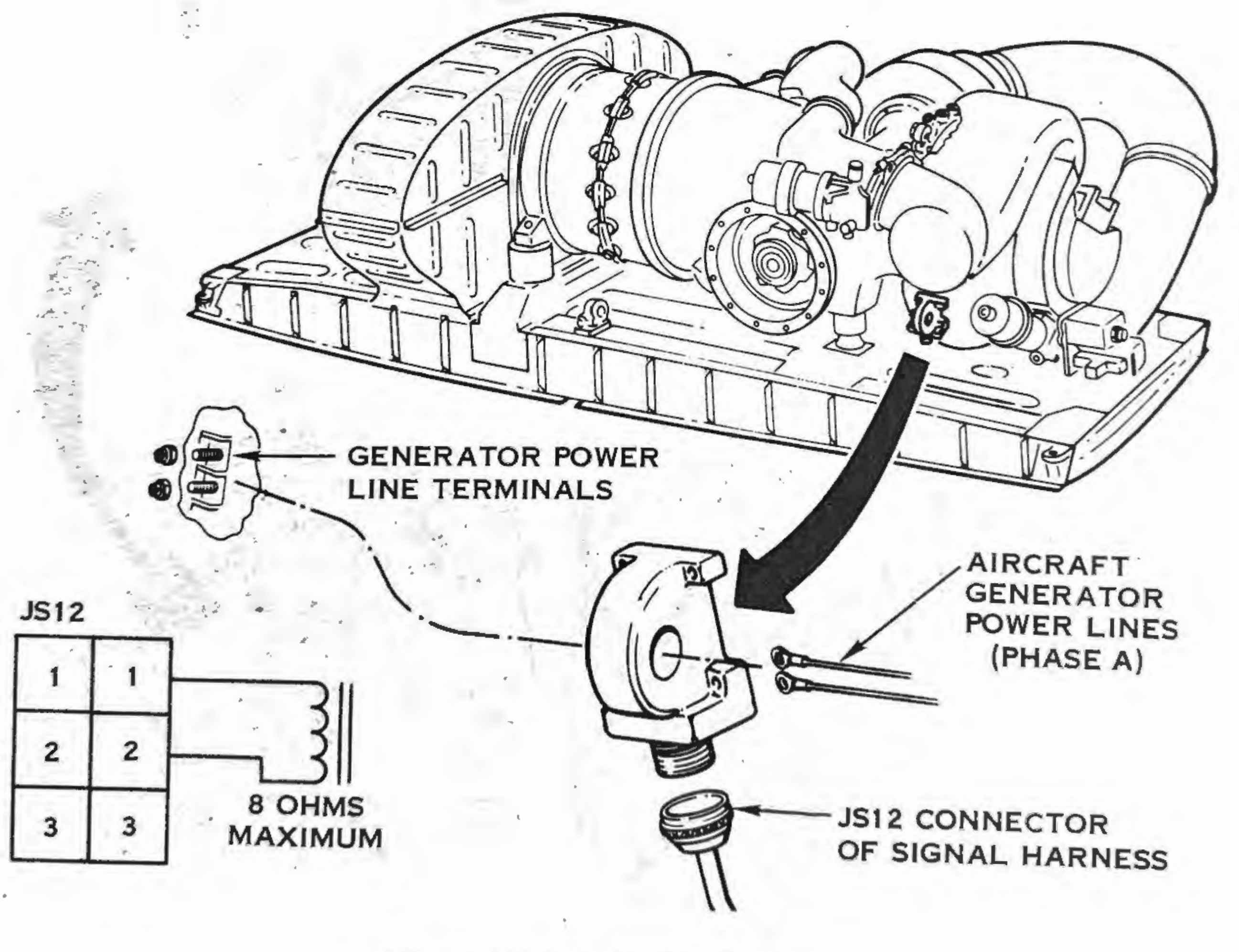
ELAPSED TIME INDICATOR
FIGURE 3-2

Current Transformer Description and Operation

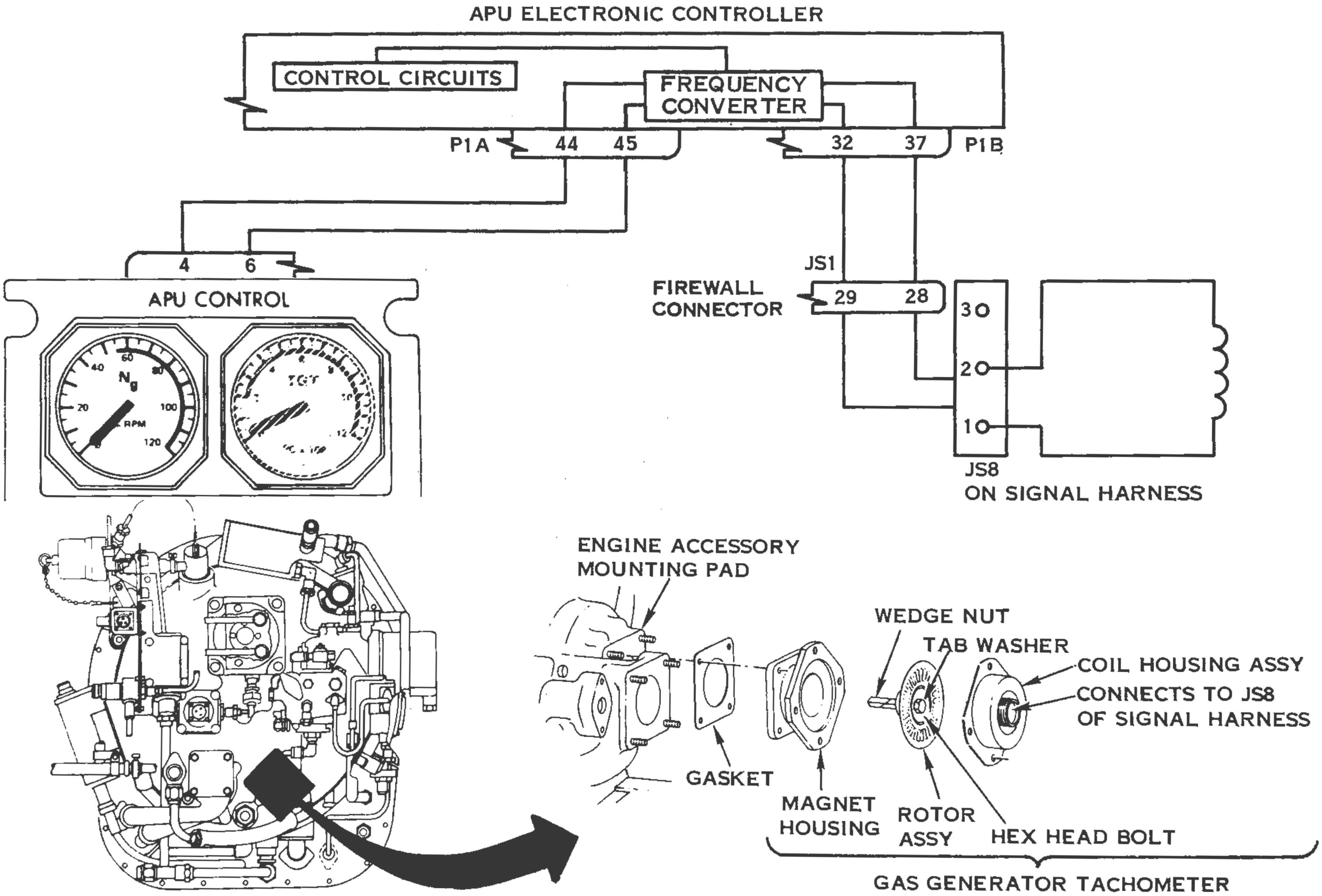
The current transformer (Figure 3-3) is a sealed unit that mounts below the load compressor outlet and adjacent to the generator pad. The two number four wires of one phase of the aircraft generator harness pass through the center of the current transformer.

The current transformer senses the output current flow of phase "A" of the APU driven 3 phase 400 Hz ac generator and through the signal and aircraft harnesses provides the APU Electronic Controller with a signal proportional to the current generated.

The current ratio of the transformer is 1000 to 1 and the output will vary over the range of 0 to 271 milliamperes.



CURRENT TRANSFORMER
FIGURE 3-3



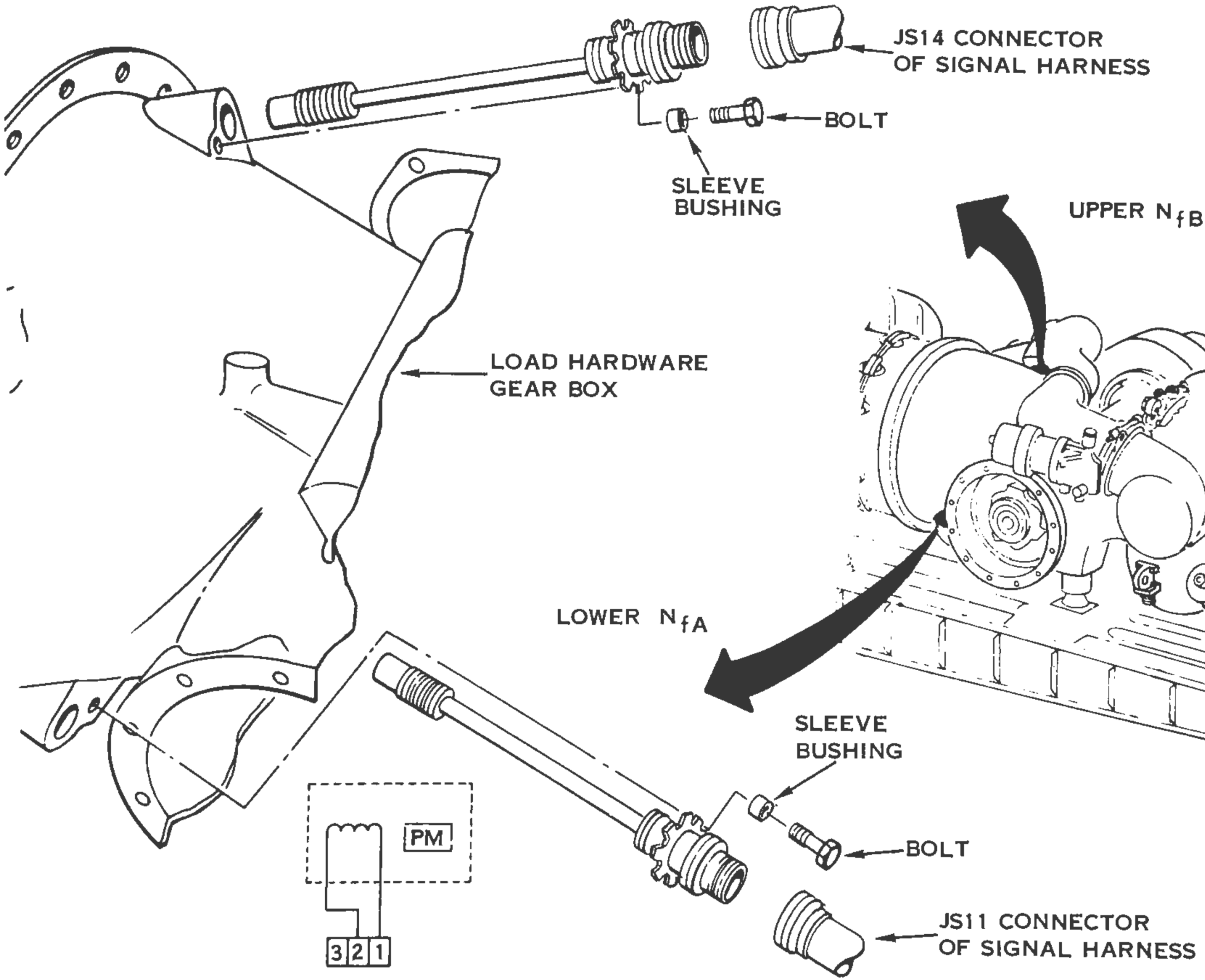
GAS GENERATOR TACHOMETER
FIGURE 3-4

Gas Generator Tachometer Description and Operation

The gas generator tachometer (Figure 3-4) consists of a circular rotor and shaft held between a coil and a magnet housing. The tachometer mounts on the engine accessory gearbox where the rotor shaft mates with the engine shaft.

As the engine gas generator rotates, it turns the tachometer rotor through a magnetic field inducing a voltage output from the coil. The ac voltage signal is supplied by the signal harness and aircraft wiring to the APU Electronic Controller which modifies the signal and sends a proportional signal to the N_g indicator on the APU CONTROL panel for information purposes while separately conditioning and using the N_g data for control purposes.

NOTE: Unless the main housing is damaged, only the rotor and/or cover usually requires replacement. Refer to 49-00-01 for correct disassembly and assembly procedures.



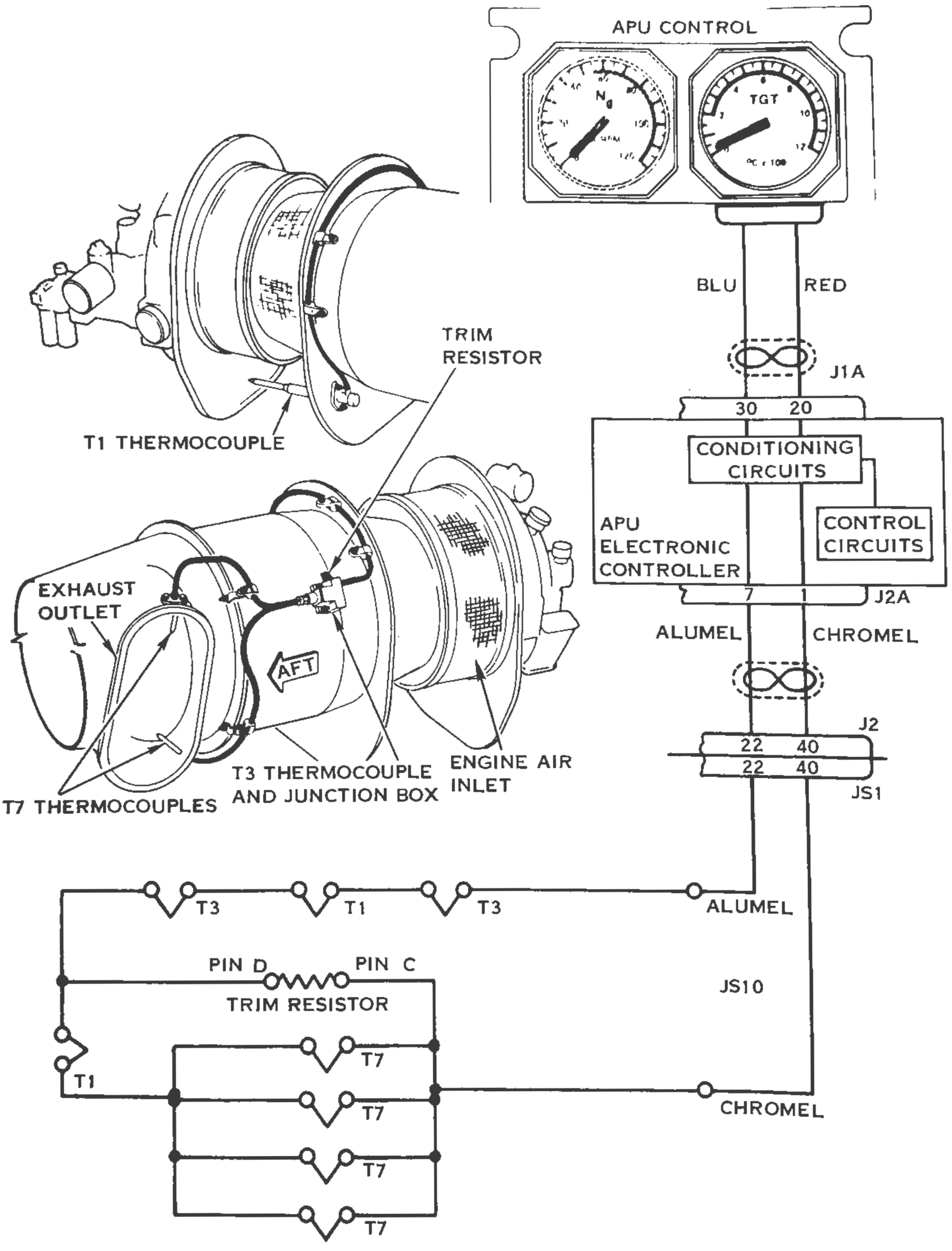
FREE TURBINE SPEED SENSORS
FIGURE 3-5

Free Turbine Speed Sensor Description and Operation

Two free turbine speed sensors (Figure 3-5) mount through ports in the load hardware gearbox housing. Each sensor consists of a permanent magnet and coil in a stainless steel case. Normal resistance between pins 1 and 2 is 1400-2000 ohms for P/N 738703-1 units and 16-24 ohms for 738703-2 sensors.

As the free turbine shaft rotates, segments on the rotating flange coupling pass the end of the sensor magnets inducing an electrical signal proportional to free turbine speed. This signal is carried via the signal harness and aircraft wiring to the APU Electronic Controller which adjusts the free turbine speed controller and load compressor controller position to suit system requirements.

The APU Electronic Controller will schedule protective shutdowns if an N_fA signal is not present when N_g passes 55%, if N_fA or N_fB exceed 110% and if either signal is lost or shorts to ground while the APU is operating. The APU Electronic Controller will permit the "generator control unit" to put the APU driven generator "on the line" only if N_fB is between 95% and 100% speed and no fault condition exists.



T1,T3,T7 TEMPERATURE SENSING HARNESS
FIGURE 3-6

T1, T3, T7 Temperature Sensing Harness Description

The T1, T3, T7 temperature sensing harness (Figure 3-6) consists of four chromel/alumel thermocouple probes and a trim resistor joined by wiring that encircles the engine. The T1 probe mounts in the engine inlet, the T3 probe mounts into the gas generator, and two T7 probes mount into the engine exhaust. The subscript numbers refer to the ST6L-73 engine station number. Each probe contains two thermocouples. The harness connects to the APU Electronic Controller by insulated chromel and alumel wires covered with stainless steel braiding forming parts of the signal and aircraft harnesses.

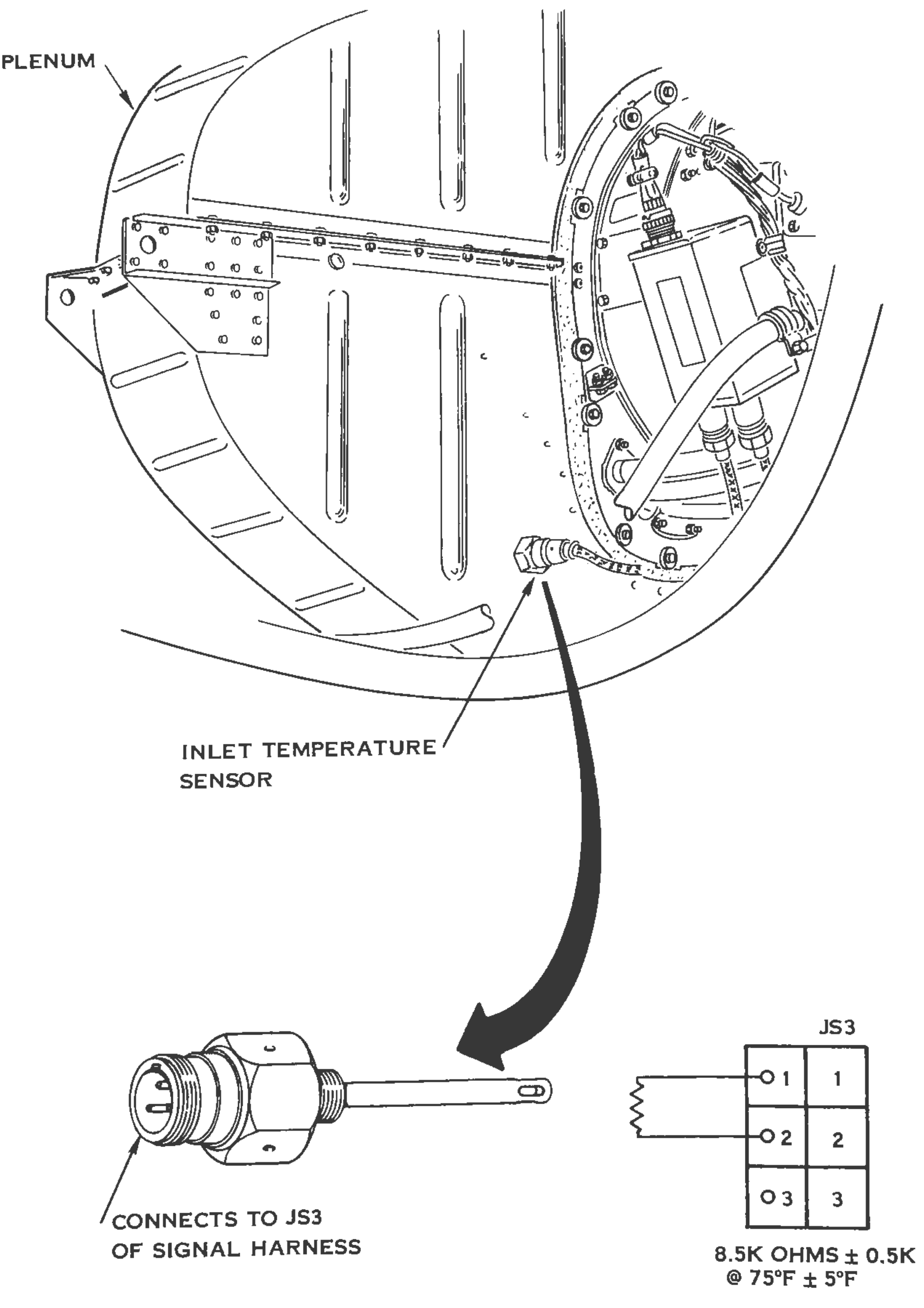
T1, T3 T7 Temperature Sensing Harness Operation

Due to engine turbine blade containment design, thermocouple probes cannot be mounted in the combustion chamber to measure T_4 temperature. A simulated TGT signal is obtained by sensing T_1, T_3 and T_7 temperatures.

Each thermocouple generates a voltage proportional to temperature. The two thermocouples contained in each of the T1 and T3 probes are connected in series with reversed polarities. The four thermocouples contained in two T_7 probes are connected in parallel acting as one thermocouple and providing an average exhaust temperature. The parallel T7 thermocouples are connected in series with the T3 and T1 probes so that the voltages add producing a signal equal to $T_7 + 2\ (T_3 - T_1)$. Since the exact compressor/turbine temperature ratio is subject to blade tip clearances and other factors, the exact T4 temperature is measured during engine testing and a trim resistor is selected and matched to the T1, T3, T7 temperature sensing harness to compensate for these variables. The simulated T_4 (TGT) signals sent to the APU Electronic Controller are modified and used in control scheduling and shutdown protection. The TGT signal is also separately conditioned and then sent to the TGT indicator on the APU Control Panel for information purposes.

T1, T3, T7 Temperature Sensing Harness Leading Particulars

Test Point	Resistance
• Chromel to Alumel	3.87 to 4.73 ohms
• Chromel to Pin C	0.05 to 0.08 ohms
• Pin C to Pin D	2.07 to 2.53 ohms
• Alumel to Pin D	1.85 to 2.26 ohms
• Between Each Terminal and Ground	20 K ohms minimum
• Shield to Ground	Zero ohms

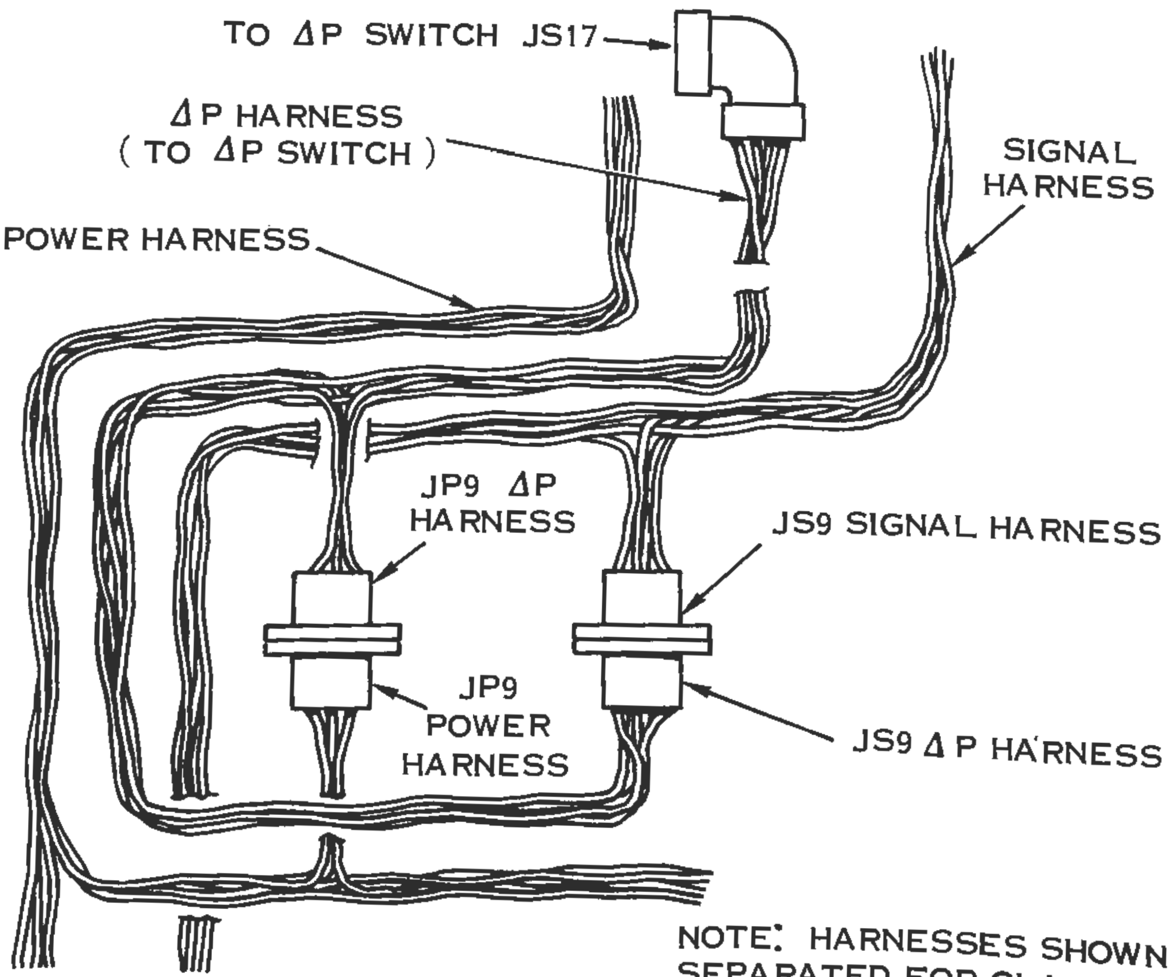


INLET TEMPERATURE SENSOR
FIGURE 3-7

Inlet Temperature Sensor Description and Operation

The inlet temperature sensor (Figure 3-7) consists of a thermistor encased in a probe and mounted into the engine inlet air plenum. The probe connects via signal and aircraft harnesses to the APU Electronic Controller and serves as the feedback resistor for an APU Electronic Controller internal amplifier.

As the temperature of engine inlet air decreases, the thermistor resistance increases. This change in resistance provides a signal to the APU Electronic Controller to schedule guide vane position at the load compressor inlet and vary the gas generator speed topping point.



ΔP, SIGNAL AND POWER HARNESS INTERCONNECT
FIGURE 3-8

ΔP Harness Description and Operation

The ΔP harness (Figure 3-8) consists of wire bundles interconnecting the ΔP switch, the APU power harness and the APU signal harness.

ΔP Harness Leading Particulars

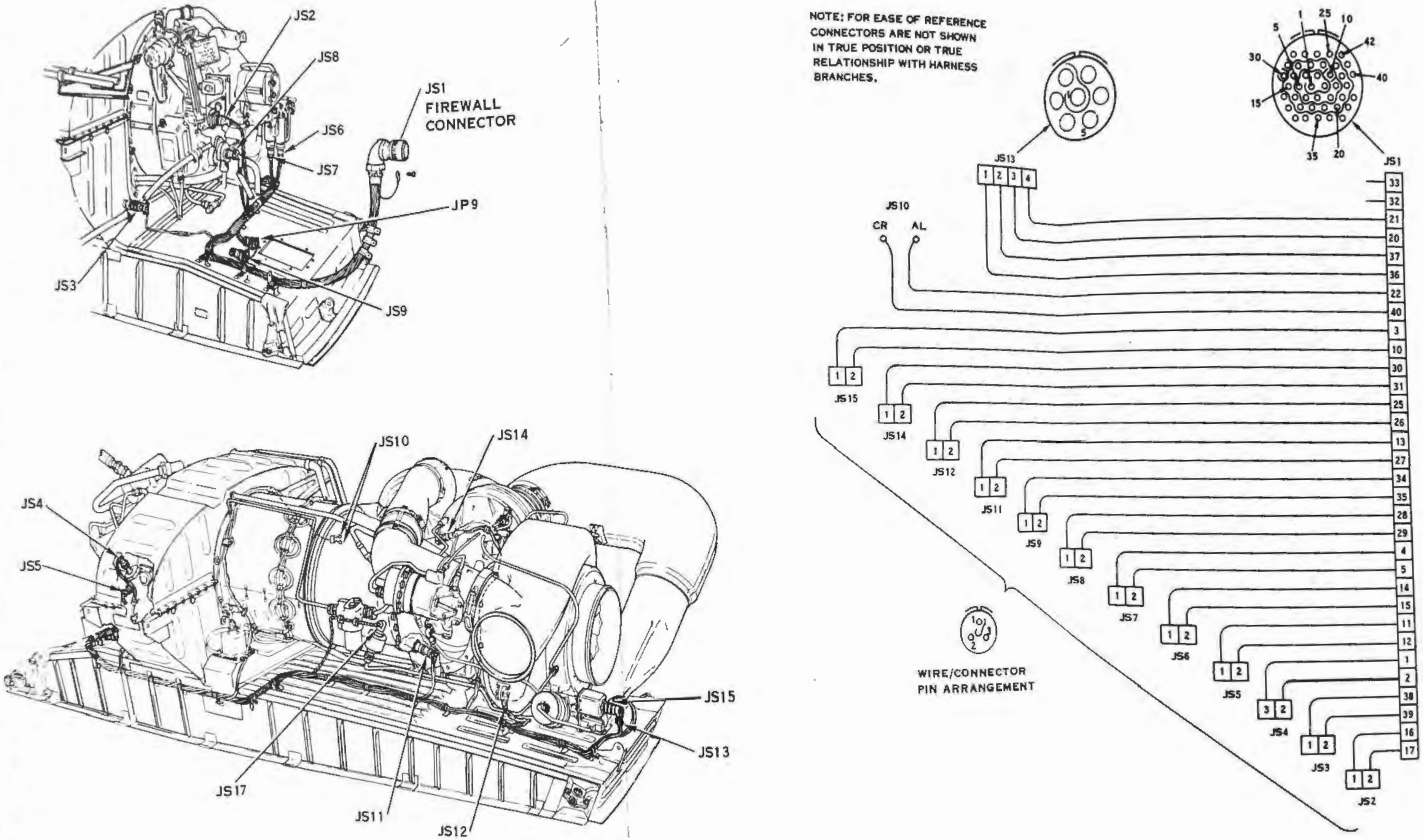
APU Component Nomenclature	Connector Designation	Connector Part Number
• ΔP Switch	JS17	MS3108R10SL3S
• Power Harness Interconnect	JP9	FPK112430PT
• Signal Harness Interconnect	JS9	FPK112842PTW10

Signal Harness Description and Operation

The signal harness (Figure 3-9) consists of wire bundles interconnecting thirteen electrical connectors, a firewall connector and a set of thermocouple terminals. This harness carries signals from various sensing components to the firewall connector and through aircraft wiring to the APU Electronic Controller. The harness connectors are identified by the mating components and connector designators. The signal harness interconnects through the ΔP harness to the power harness.

Signal Harness Leading Particulars

APU Component Name	Connector Designation	Connector Part Number
• Firewall Connector (Signal)	JS 1	Pyle National P/N FPK112842PTW10
• Free Turbine Speed Controller (N_f Speed)	JS 2	MS 24266R12T3SN
• Inlet Temperature Sensor (T_{t2})	JS 3	MS24266R12T3SN
• Low Oil Pressure Switch	JS 4	MS24266R12T3S10 or MS24266R12T3S10X
• High Oil Temperature Switch	JS 5	MS24266R12T3S8 or MS24266R12T3S8X
• Fuel Shutoff Valve	JS 6	MS24266R12T3S6
• Fuel Bypass Valve	JS 7	MS24266R12T3SN
• Gas Generator Tachometer (N_g)	JS 8	MS24266R12T3S6X or MS24266R12T3S6
• ΔP Harness Interconnect	JS 9	MS24266R12T3SN
• T_1, T_3, T_7 Temperature Sensing Harness (TGT)	JS 10	Terminals
• Free Turbine Speed Sensor (N_{fA})	JS 11	MS24266R12T3SNX or MS24266R12T3SN
• Current Transformer	JS 12	MS24266R12T3SN
• IGV Feedback Transducer	JS 13	MS24266R14T7SNX or MS24266R14T7SN
• Free Turbine Speed Sensor (N_{fB})	JS 14	MS24266R12T3SN or MS24266R12T3SNX
• Load Compressor Controller	JS 15	MS24266R12T3SNX or MS24266R12T3SN



SIGNAL HARNESS
FIGURE 3-9

APU CONTROL SYSTEM

GENERAL

To provide control of the Auxiliary Power Unit (APU) during all phases of its operation, an electronic control system is employed. The control system consists of an APU Electronic Controller, an internal APU CONTROL panel, an external APU control panel, numerous aircraft mounted relays and indicators, and APU engine mounted sensors and controls (Reference Figure 4-1).

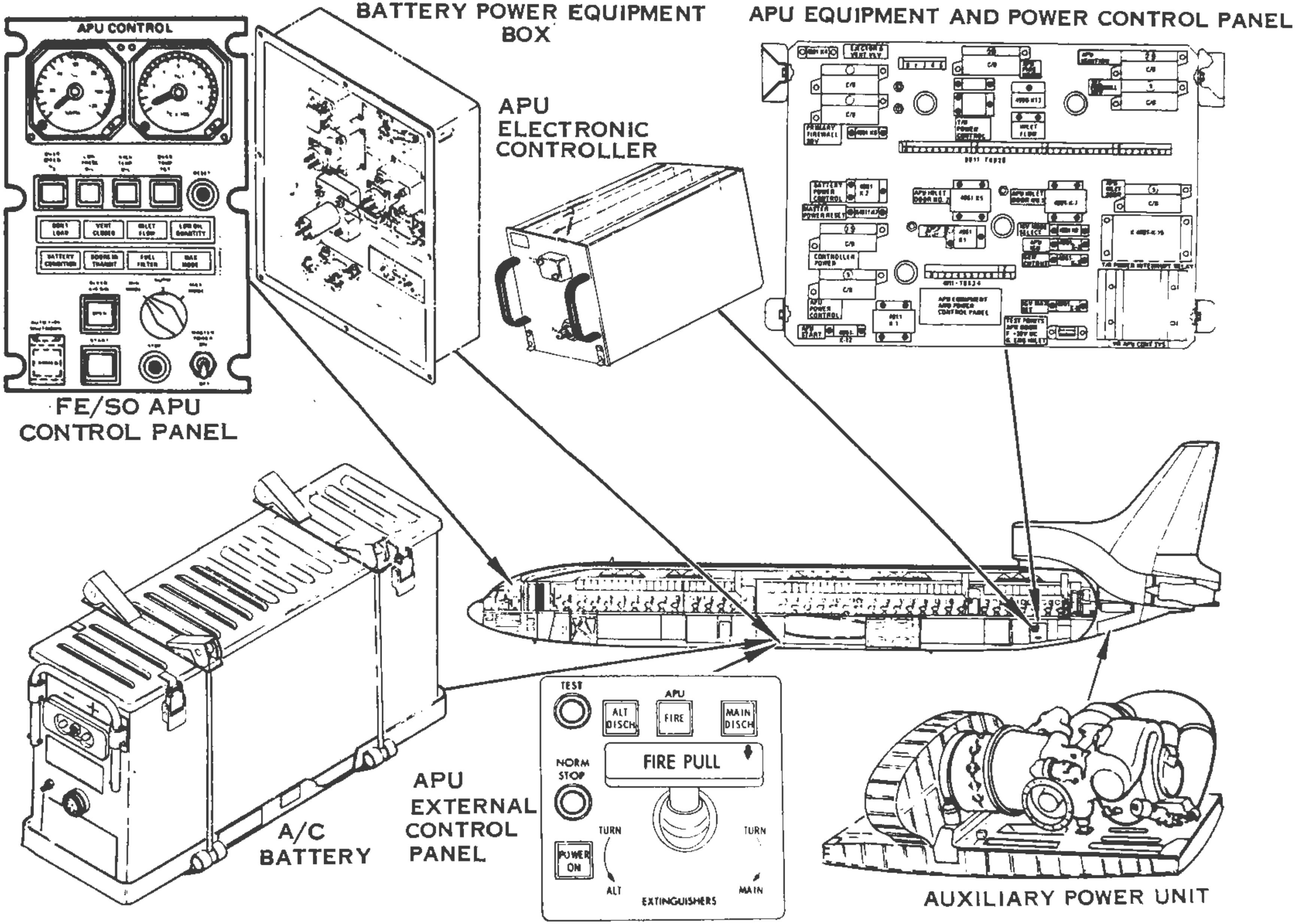
The APU Electronic Controller gives priority to maintaining constant generator frequency if the combined electrical and pneumatic demands exceed the output capacity of the APU. The APU Electronic Controller responds to manual input commands and sensor outputs to automatically provide the following APU engine functions:

- Start Sequence
- Shutdown Sequence
- Steady State Control
- Transient Control
- APU Generator Frequency Control (Free Turbine Speed Control)
- Protection of the APU engine by means of automatic shutdown is provided in the event one or more of the following conditions exists:
    - N_f Overspeed
    - Loss of N_{fA} Speed Signal
    - Loss of N_g Speed Signal
    - Low Lubricating Oil Pressure
    - High Lubricating Oil Temperature
    - High TGT
    - Power Interruptions
    - Inlet Door Malfunctions
    - Inlet Pressure ΔP

The operation of the aircraft relay logic, APU Electronic Controller sequencer, and APU steady state control is best described in terms of a normal APU start and stop cycle.

The text of this section is organized into:

- Major Control System Components
- Controls and Indicators
- Power Circuits
- Start Sequence
- Manual Shutdown Sequence
- Automatic Shutdown Circuits
- Modulating Controls
- Fail-Safe Provisions



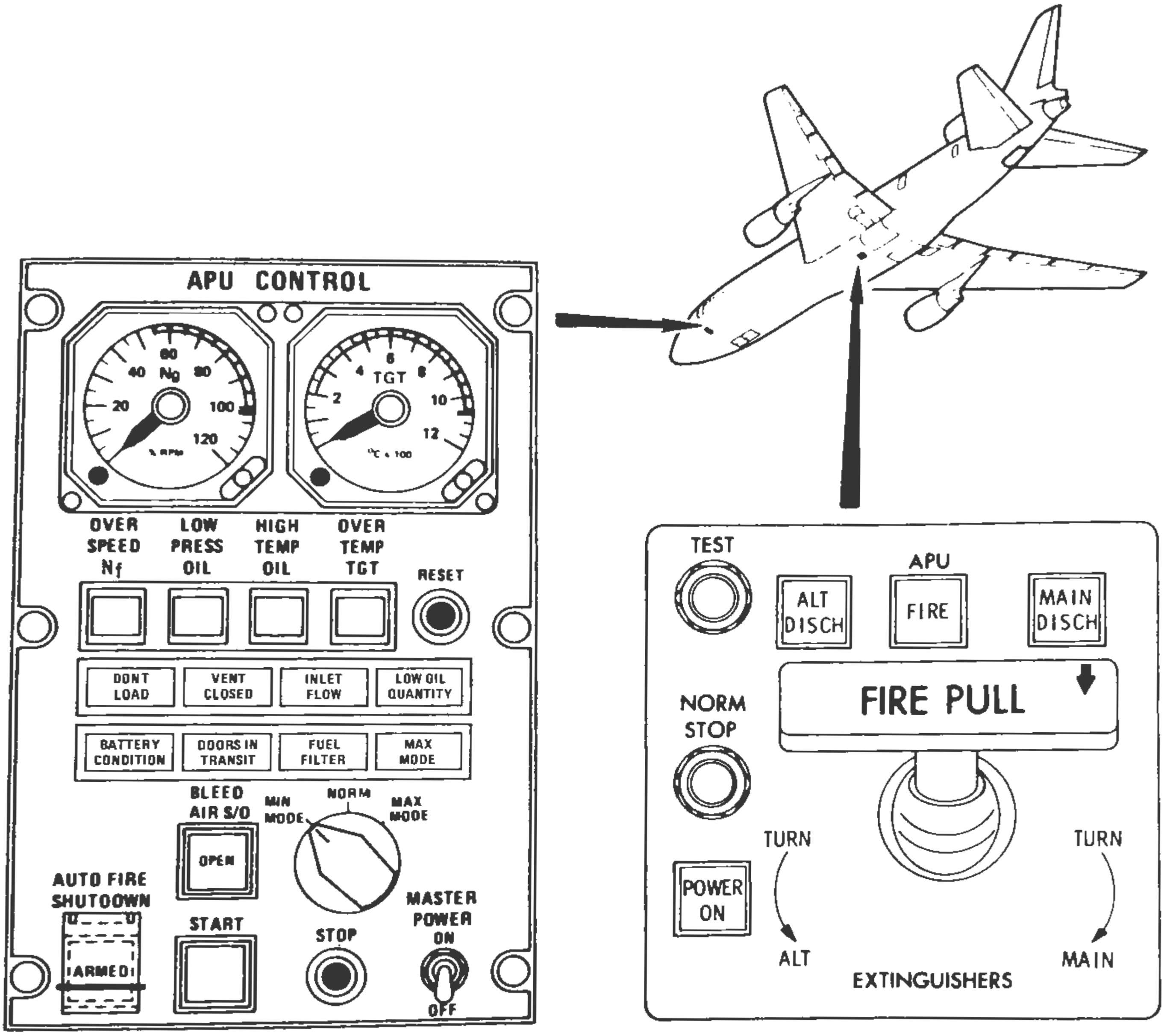
APU AND CONTROL SYSTEM COMPONENT LOCATIONS
FIGURE 4-1

MAJOR CONTROL SYSTEM COMPONENTS

The major components of the APU control system (Figure 4-1) are located in the Flight Station, Aft and Mid Electronic Service Centers, the underside of the fuselage, and within the APU Compartment. These components are listed below by location. The APU CONTROL panel and external APU control panel (Figure 4-2) are described in detail under CONTROLS AND INDICATORS. Relay logic and remote control circuit breakers (Figures 4-3 and 4-4, sheet 2) are described under POWER CIRCUITS. The APU Electronic Controller (Figure 4-4, sheet I) is described separately. To aid in understanding the complete APU and control system, the system wiring is shown (Figure 4-5, sheets 1 through 9) and then broken down into simplified schematics (Reference Figures 4-6 through 4-15, 4-17, 4-19, 4-20 and 4-22) to simplify discussion. Each simplified functional diagram presents the wiring connections of a single major function, or a series of related simple functions, on a single sheet.

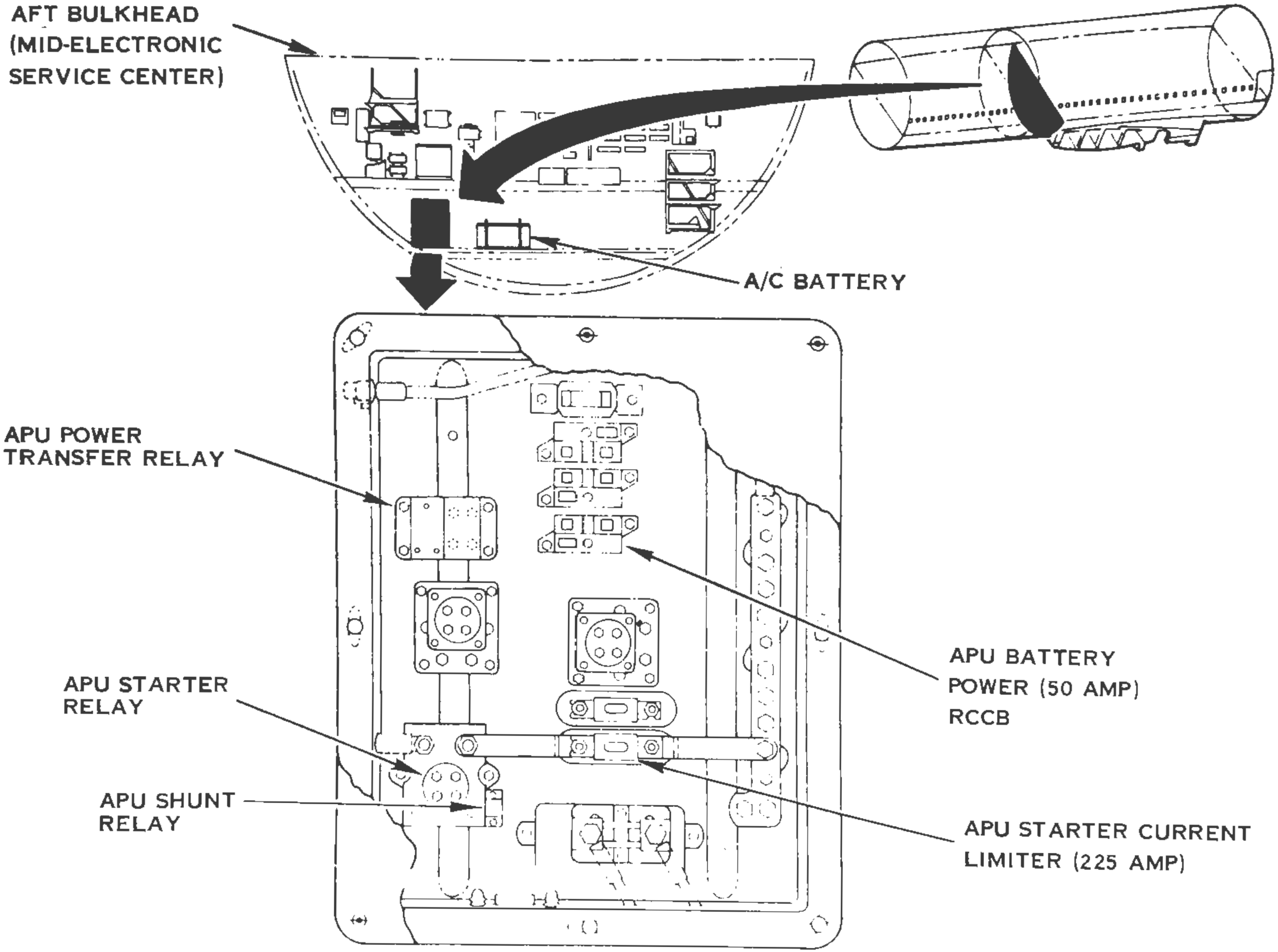
Location and Component	Function
Flight Station	
• APU CONTROL Panel	Control and Indication
• APU Auto Indication Shutdown Relay	Indication
Aft Electronic Service Center	
• APU Electronic Controller	APU Control
• APU Equipment and Power Control Panel	System Interface
• • APU Ignition Relay	APU Ignition
• • APU Inlet Door Relays No. 1 and 2	Inlet and Ejector Door Position Control
• • APU Primary Firewall SOV Relay	Fire Shutdown and Normal Shutdown
• • Battery Power Control Relay	Transfer of Continuous Power
• • IGV Max Select Relay	Pneumatic Load Control
• • IGV Mode Select Relay	Pneumatic Load Control
• • Generator Cutout Relay*	Transfer of Continuous Power
• • Master Power Reset Relay	Start/Stop Control and Remote Power Off
• • APU Power Control Relay	Controller Power Supply
• • APU Start Relay	Start/Stop Control
• • Inlet Flow Shutdown Relay	ΔP Shutdown
• • APU Stop Relay	Start/Stop Control
• • T/R Power Control Relay*	Transfer of Continuous Power
• • T/R Power Interrupt Relay	Transfer of Continuous Power
• • Ejector and Vent Valve Relay	Vent Valve Control
• • APU Inlet Door RCCB	Circuit Breaker
• • Ejector and Vent Valve RCCB	Circuit Breaker

*Not applicable for aircraft S/N 1038 and later



INTERNAL AND EXTERNAL APU CONTROL PANELS
FIGURE 4-2

Location and Component	Function
Aircraft Electronic Service Center	
• • Secondary Firewall SOV RCCB	Circuit Breaker
• • Primary Firewall SOV RCCB	Circuit Breaker
• • APU Ignition RCCB	Circuit Breaker
• • APU Power Control RCCB	Circuit Breaker
• • Controller Power RCCB	Circuit Breaker
• • APU Fire Horn RCCB	Circuit Breaker
Mid Electronic Service Center	
• APU Power Transfer Relay	APU Battery Bus Transfer
• Auto Fire Shutdown Relays No. 1 and 2	Fire Shutdown
• APU Starter Relay	Start Control
• Main Engine Ground Start Relays	Pneu Load Control
• APU Battery Power RCCB	Circuit Breaker
• APU Shutdown Mode Relay	Auto/Manual Fire Shutdown Select
• 225 Amp APU Starter Current Limiter	Safety Feature
Fuselage Underside	
• External APU Control Panel	APU Shutdown Function
APU Compartment	
• APU Engine Starter	Engine Start Effector
• Ignition Exciter	Engine Ignition Effector
• Fuel Shutoff Valve	Start/Stop Control Effector
• Fuel Bypass Valve	Start/Stop Control Effector
• APU Engine Inlet Door and Vent Ejector Door	APU Engine Air Supply and Compartment Ventilation
• IGV Load Compressor Controller (Torque Motor)	Pneumatic Load Control Effector
• IGV Feedback Transducer	Pneumatic Load Control Signal Source
• Free Turbine Speed Controller (Fuel Torque Motor)	Speed Control Effector
• T_1, T_3, T_7 Temperature Sensing Harness	Engine Turbine Temperature Signal Source
• Gas Generator (N_g) Tachometer	Speed Control Signal Source
• Free Turbine Speed (N_{fA}) Sensor	Speed Control Signal Source
• Free Turbine Speed (N_{fB}) Sensor	Speed Control Signal Source
• Inlet Temperature (T_{t2}) Sensor	Speed and Pneumatic Load Control Signal Source
• Current Transformer	Load Transient Signal Source



APU RELAYS AND BATTERY POWER EQUIPMENT BOX
(MID ELECTRONIC SERVICE CENTER)
FIGURE 4-3

Location and Component	Function
• Low Oil Pressure Switch	Shutdown Protection Signal
• High Oil Temperature Switch	Shutdown Protection Signal
• ΔP Switch	Shutdown Protection and Panel Information Signal
• Clogged Fuel Filter Switch	Control Panel Information Signal
• Float Switch (Low Oil Quantity)	Control Panel Information Signal
• Elapsed Time Indicator	Information
Adjacent to APU Compartment	
• APU Firewall Shutoff Valves	Start/Stop Control
• Vent Air Exhaust Valve	APU Compartment Ventilation
• APU Isolation Valve (Bleed Air S/O Valve)	Pneumatic Supply

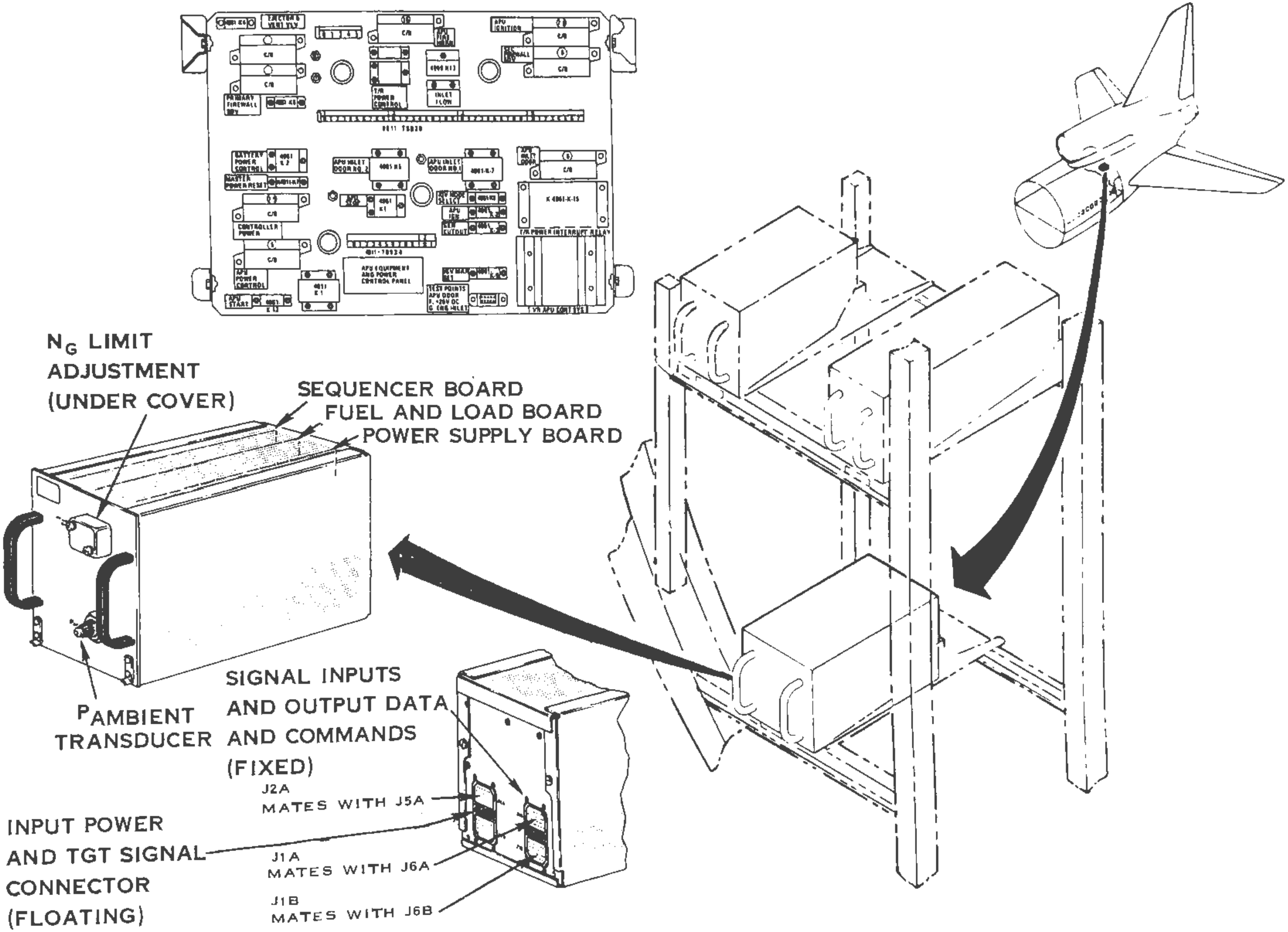
APU Electronic Controller

The APU Electronic Controller mounts on a rack in the aft electronic service center, on the right side of the aft cargo compartment (Reference Figures 4-1 and 4-4) and is cooled by natural convection and conduction. The APU Electronic Controller contains three printed circuit boards interconnected by a mother board. The APU Electronic Controller is connected to aircraft wiring through two connectors on the rear of the case and a pneumatic connection for a P ambient pressure sensor transducer on the front of the case. An Ng limit adjustment (trim speed) potentiometer is also located on the front panel under a protective cover.

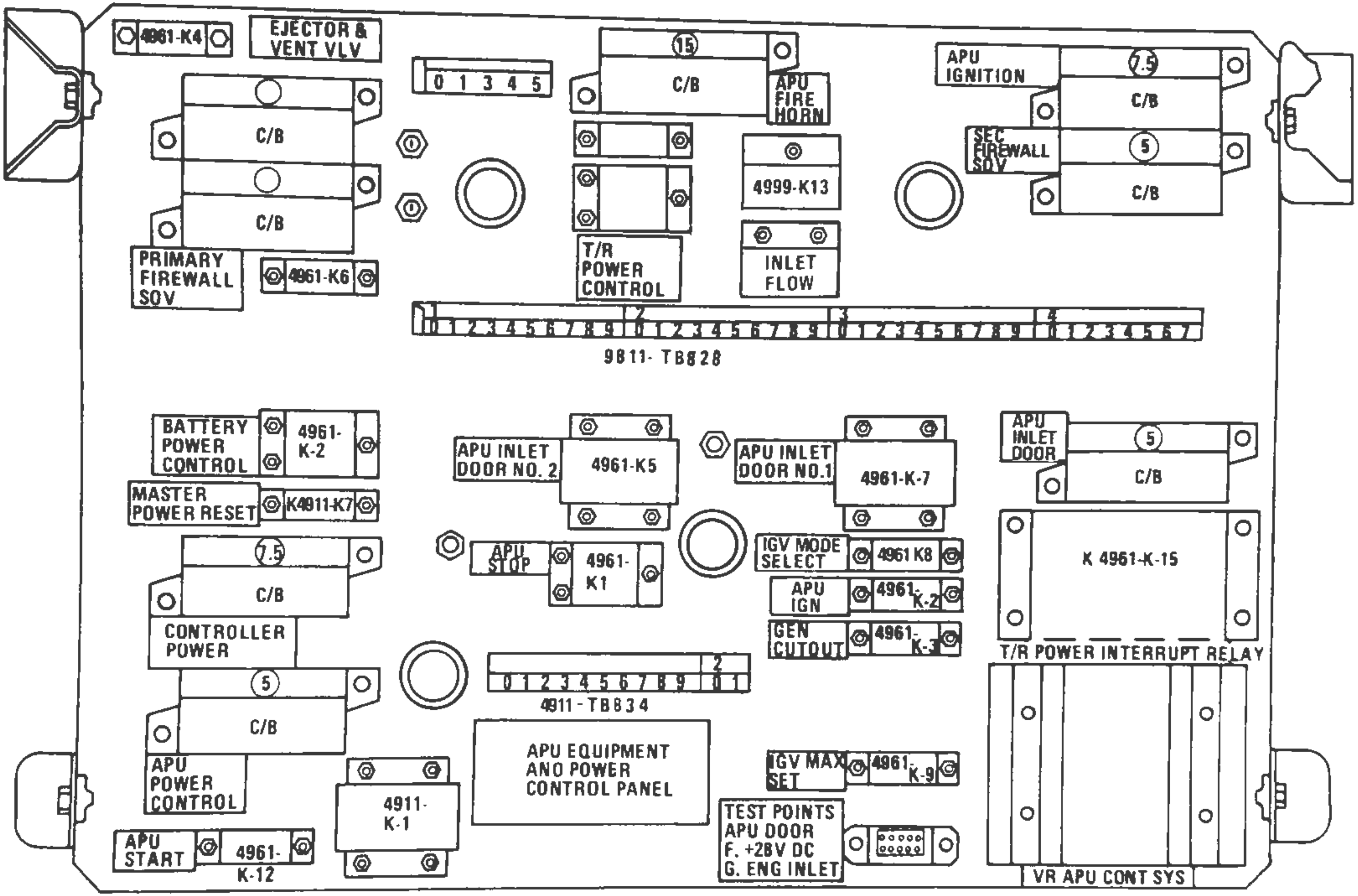
Two fundamental subsystems are incorporated within the APU Electronic Controller. One subsystem consists of a sequencer which controls starting, stopping, and emergency protection of the APU. The other consists of the modulating controls which include a speed control system, a load control, and a transient control, all of which interact simultaneously to protect and maintain proper control of the APU engine gas generator and free turbine speed.

Signal Inputs to APU Electronic Controller

Signal	Connector Pins	Level/Type
• N_{fA} Sensor	JIB-26 to JIB-31	4V ac Peak to Peak (Sine Wave) of Variable Frequency
• N_{fB} Sensor	J1B-40 to J1B-41	4V ac Peak to Peak (Sine Wave) of Variable Frequency



AFT ELECTRONIC SERVICE CENTER
(APU ELECTRONIC CONTROLLER)
FIGURE 4-4 (Sheet 1 of 2)



AFT ELECTRONIC SERVICE CENTER
(APU EQUIPMENT AND POWER CONTROL PANEL)
FIGURE 4-4 (Sheet 2 of 2)

	Signal	Connector Pins	Level/Type
•	N_g Sensor (-2)	J1B-37 to J1B-32	4 Vac Min (sine wave) of variable frequency
•	N_g Sensor (-1)	J1B-37 to J1B-32	10V ac Min. (Sine Wave) of Variable Frequency (4.3K input resistance)
•	T_{t2} Sensor	J1B-28 to J1B-27	0 to 20K ohms/Thermistor
•	P Ambient Sensor	Front of Chassis	2.5 to 25 psia/Pneumatic
•	Current Transformer	J1B-16 to J1B-17	0 to 0.265 amps/ac (400 Hz)
•	TGT	J2A-1 (CR) to J2A-7 (AL)	0 to 50 MV dc
•	IGV Position Feedback	J1B-10 to J1B-12 and J1B-13	0 to 8.0V dc
		J1B-20 to J1B-12 and J1B-13	+15V dc Fixed Bias
•	Max Mode Select	J1A-14 to J1A-43	Open or Closed Relay (0V dc)
•	Norm Mode Select	J1A-23 to J1A-43	Open or Closed Relay (0V dc)
•	Min Mode Select	J1A-24 to J1A-43	Open or Closed Relay (0V dc)
•	Start Command	J1A-5 to J1A-18	Open or Closed Relay (0V dc)
•	Stop Command	J1A-8 to J1A-18	Open or Closed Relay (0V dc)
•	High Oil Temperature (HOT)	J1B-44 to J1B-45	Open or Closed Switch (0V dc)
•	Low Oil Pressure (LOP)	J1B-34 to J1B-35	Open or Closed Switch (0V dc)
•	Door Malfunction or Inlet Flow ΔP	J1B-18 to J1B-39	Open or Closed Switch (28V dc)
•	N_g Limit Adjust	Access Cover	10 Turn Pot/Full CW is Min.
•	Max Mode Inlet Flow Override	J1B-18 to J1B-39	Short when max mode select relay is energized (0 Vac)

Signal Outputs from APU Electronic Controller

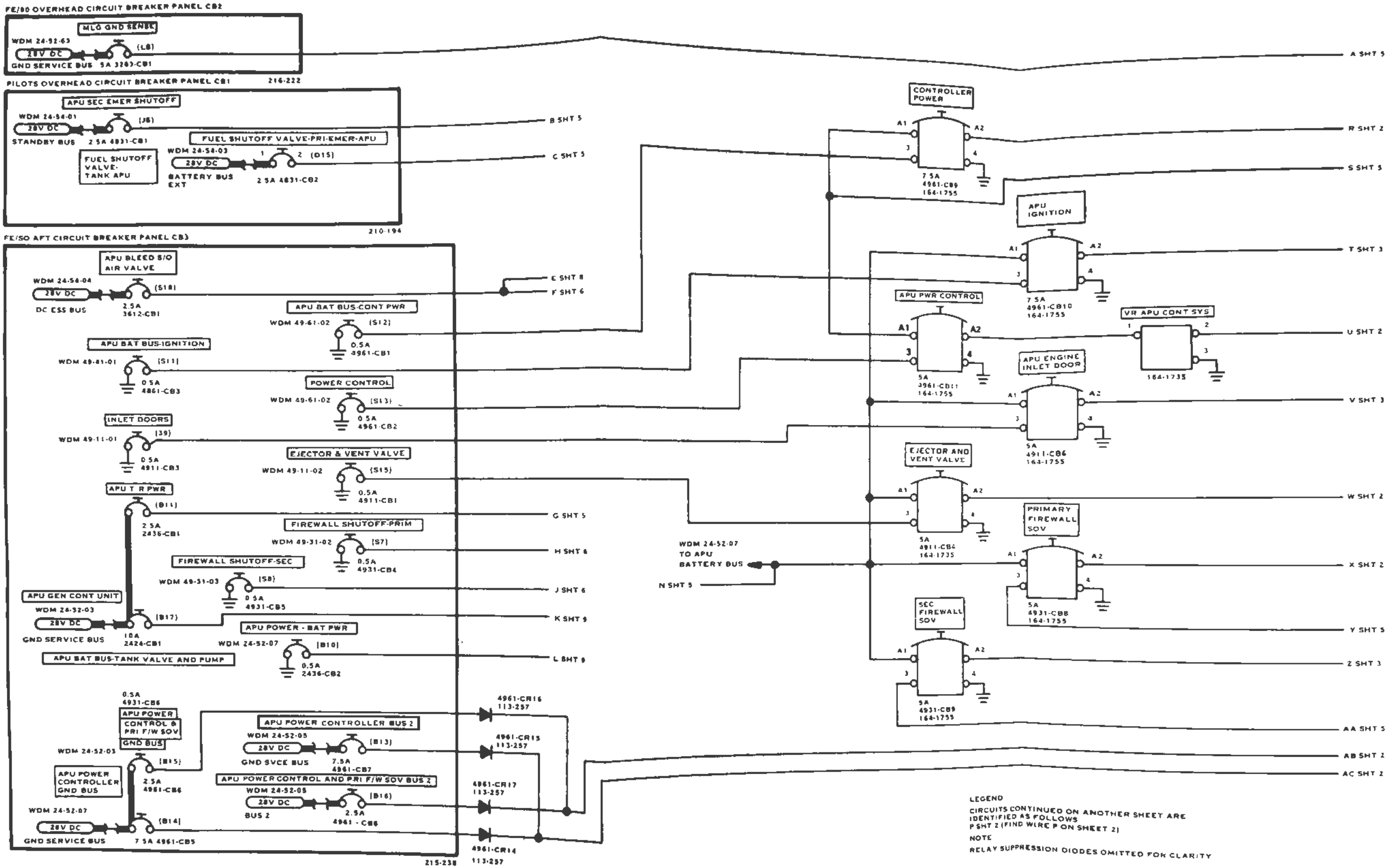
	Signal	Connector Pins	Level/Type
•	Control Signal to Torque Motor in Load Compressor Controller	J1B-19 to J1B-29	0 to 150 milliamps (at +28V dc)
•	Control Signal to Free Turbine Speed Controller (N_f Torque Motor)	J1B-21 to J1B-30	0 to 250 milliamps (at +28V dc)
•	Ignition Control	J1A-4 to J2A-5	0 or +28V dc/Relay Contacts to Relay Coil

Signal	Connector Pins	Level/Type
• Starter Control	J1A-37 to J2A-5	0 or +28V dc/Relay Contacts to Relay Coil
• Fuel Bypass Control	J1B-25 to J2A-5	0 or +28V dc/Relay Contacts to Solenoid Coil
• Fuel Shutoff Control	J1B-38 to J2A-5	0 or +28V dc/Relay Contacts to Solenoid Coil
• DONT LOAD Light and Generator Cutout Relay*	J1A-2 to J2A-5	0 or +28V dc/Relay Contacts to Relay Coil and to Indicator Light
• Generator "On speed" (Load) Signal	J1A-9 to J1A-28	Open or Closed Relay Contacts (0V dc)
• Close Inlet Door Signal	J1A-26 to J2A-5	Open or Closed Relay Contacts (0V dc)
• N_g Indicator	J1A-45 to J1A-44	0 to +5 Volt Variable Frequency Square Wave
• TGT Indicator	J1A-20 to J1A-30	0 to 1.00 milliamps
• N_f Overspeed Fault	J1A-38 to J1A-40	+28 or 0V dc/Diode Gate to Flag Coil
• Low Oil Pressure (LOP) Fault	J1A-10 to J1A-40	+28 or 0V dc/Diode Gate to Flag Coil
• High Oil Temp (HOT) Fault	J1A-39 to J1A-40	+28 or 0V dc/Diode Gate to Flag Coil
• High Turbine Temp (TGT) Fault	J1A-16 to J1A-40	+28 or 0V dc/Diode Gate to Flag Coil

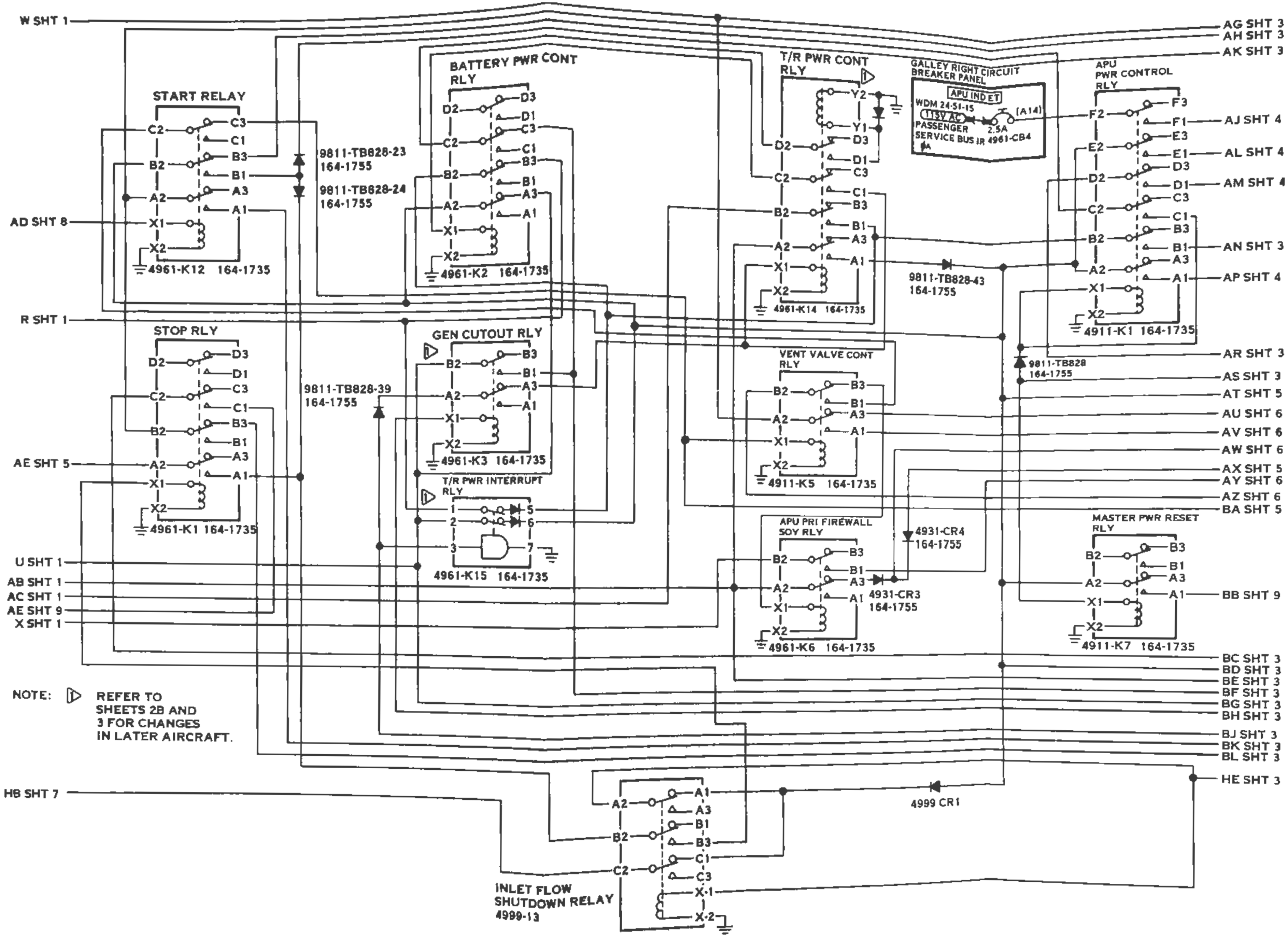
*Not applicable to aircraft S/N 1038 and later.

APU Electronic Controller Leading Particulars

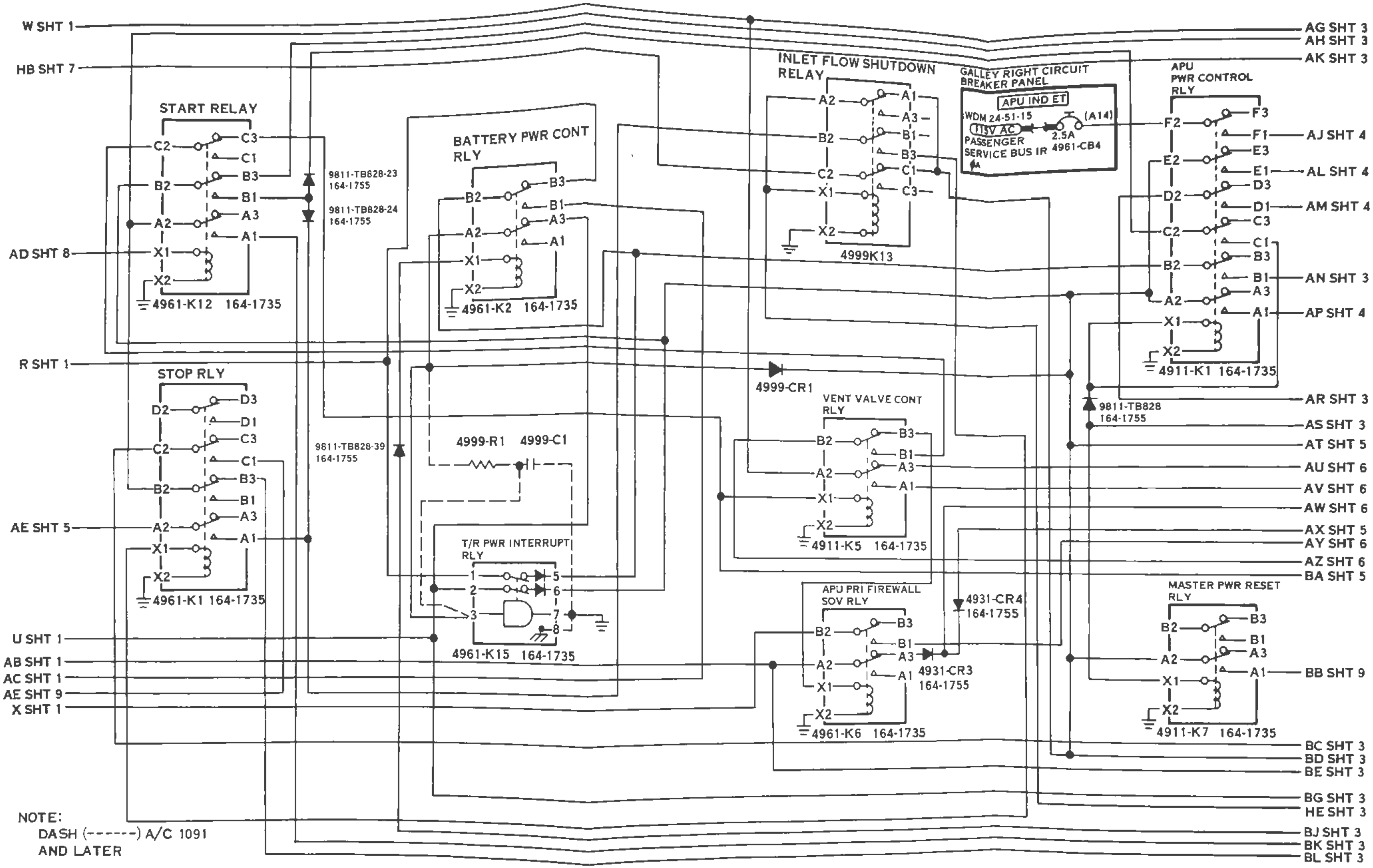
• Power Requirement/Input Voltage	J2A-6 and J2A-25 to J2A-5	15 to 38V dc at 4 amperes nominal (6.5 amperes maximum).
• P Ambient Port	MS33657-4	
• J1A and J1B Connector	Mates with DPX2MA-45S45S-33B( )01	
• J2A and J2B Connector	Mates with DPX2MA-26S26S-33B( )01	



APU AND ELECTRONIC CONTROL SYSTEM SCHEMATIC
FIGURE 4-5 (Sheet 1 of 9)

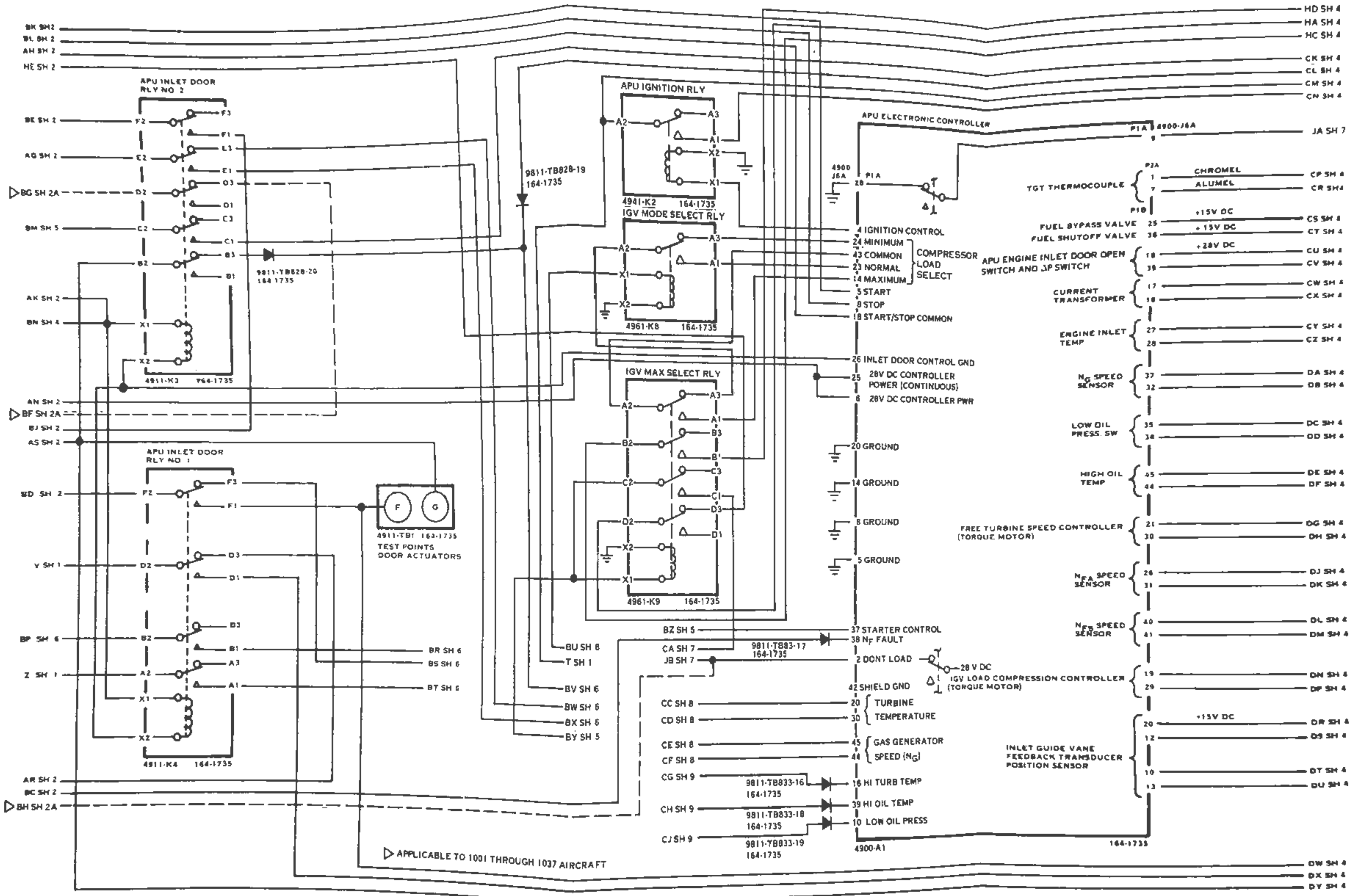


APU AND ELECTRONIC CONTROL SYSTEM SCHEMATIC
(A/C 1001 to 1037, SB30-025)
FIGURE 4-5 (Sheet 2A of 9)

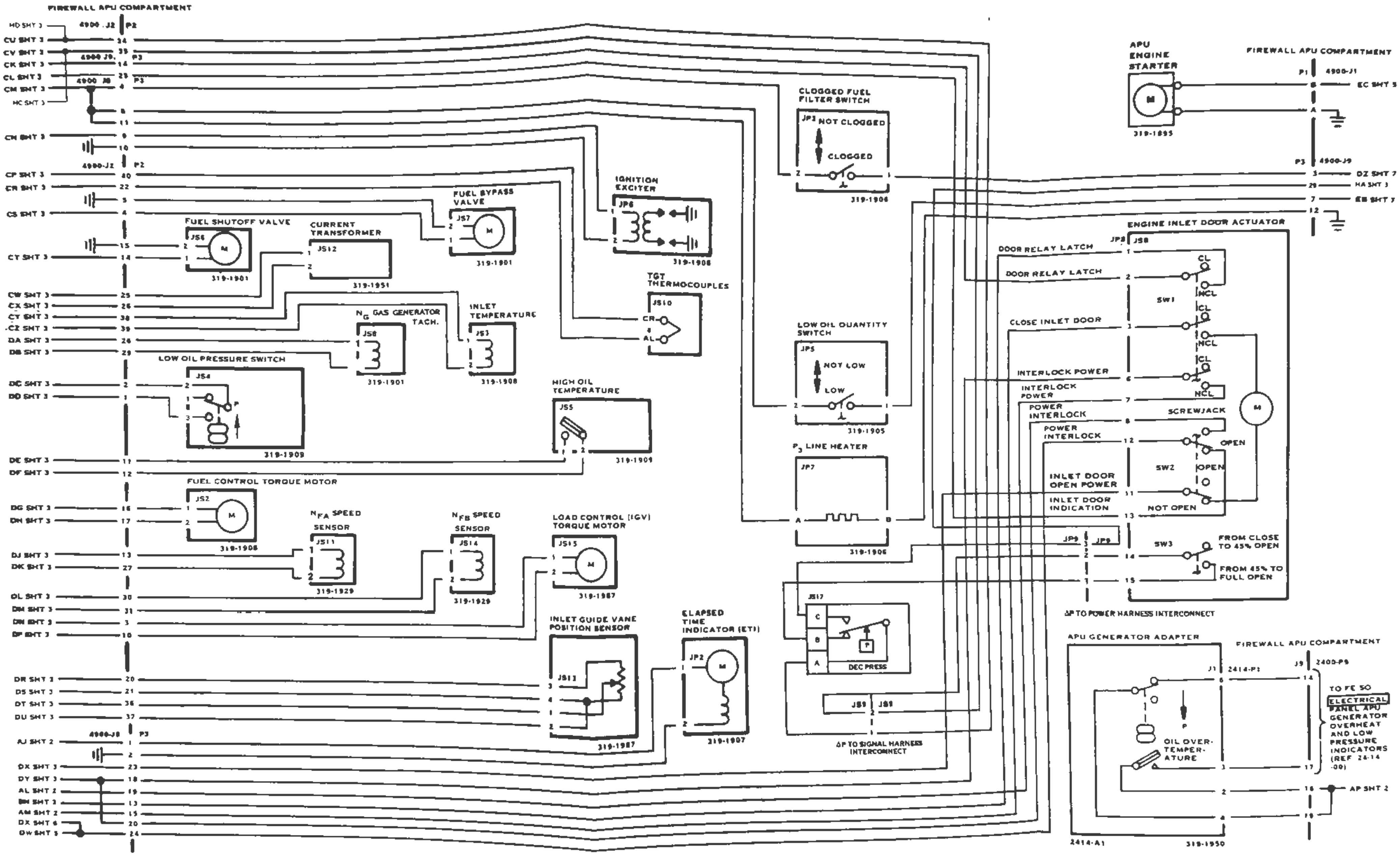


APU AND ELECTRONIC CONTROL SYSTEM SCHEMATIC
(A/C 1038 to 1090, SB30-025)

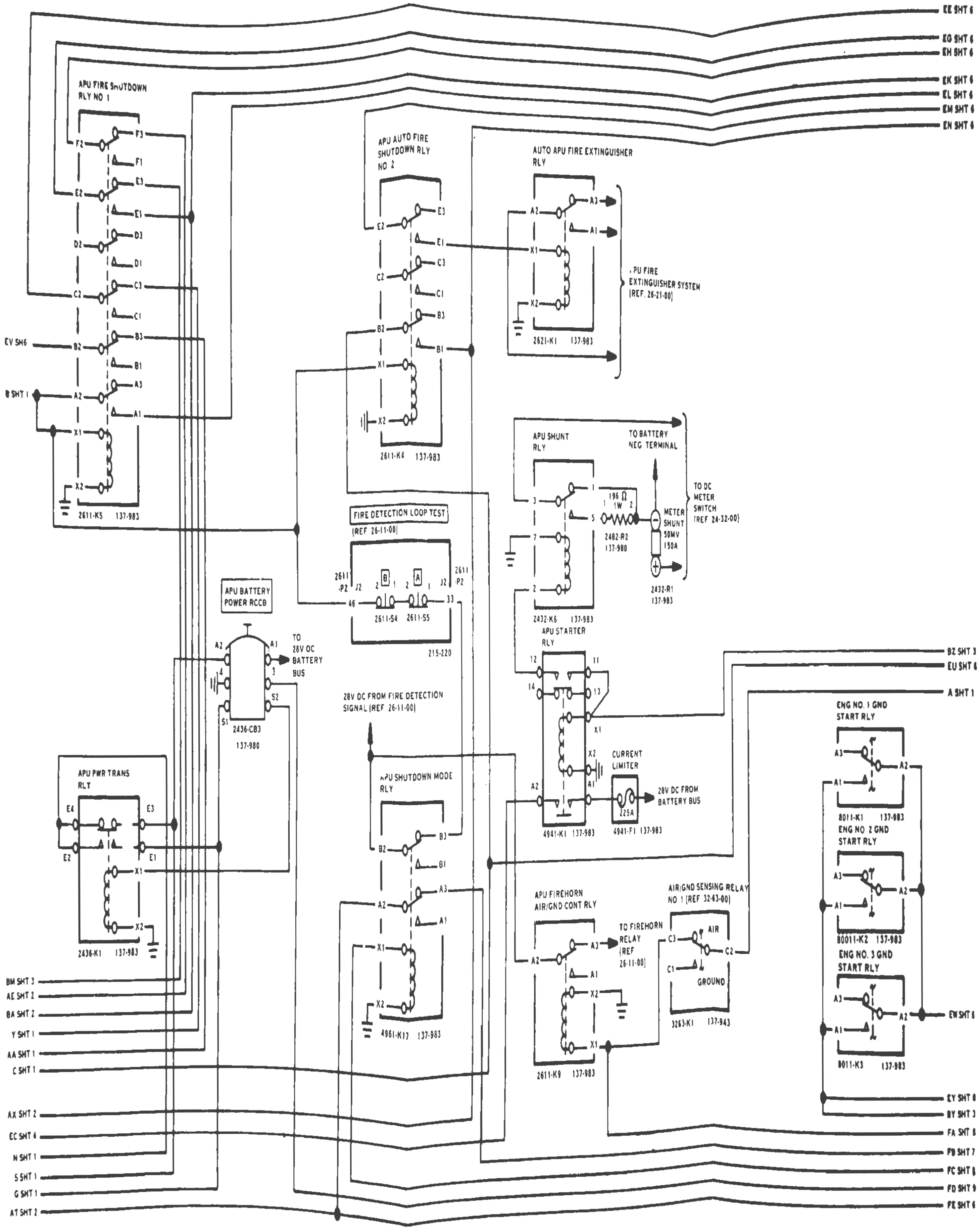
FIGURE 4-5 (Sheet 2B of 9)



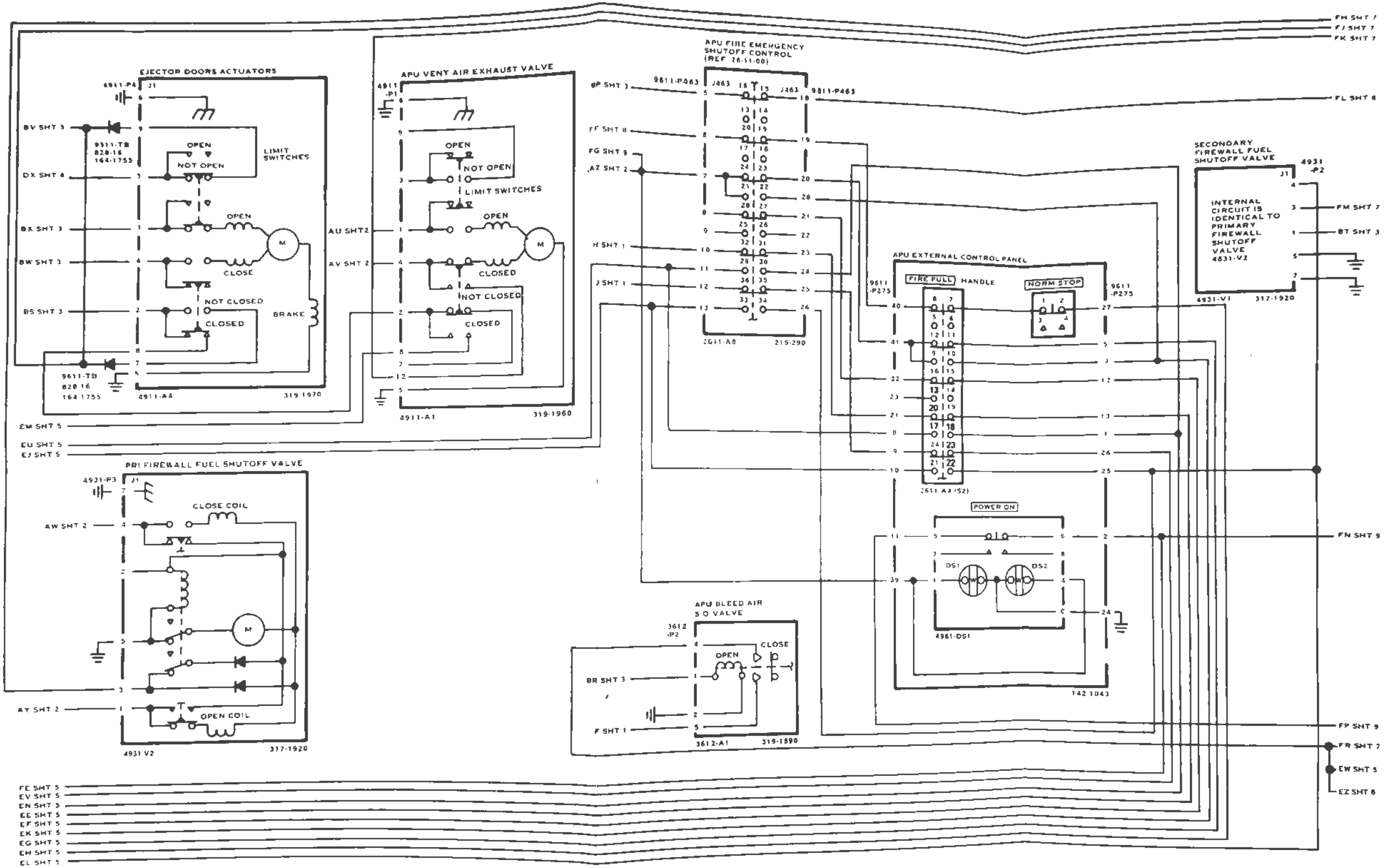
APU AND ELECTRONIC CONTROL SYSTEM SCHEMATIC
FIGURE 4-5 (Sheet 3 of 9)



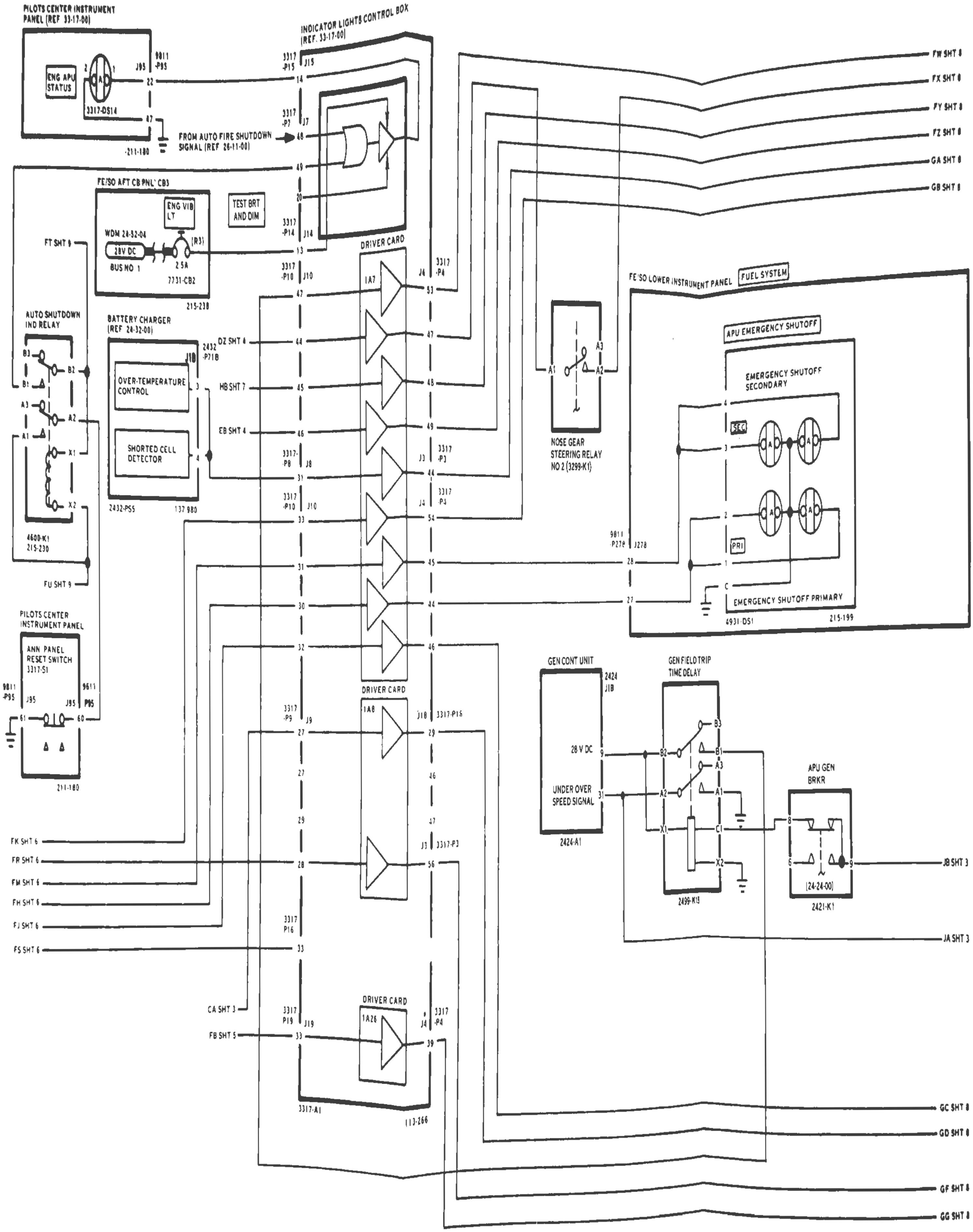
APU AND ELECTRONIC CONTROL SYSTEM SCHEMATIC
FIGURE 4-5 (Sheet 4 of 9)



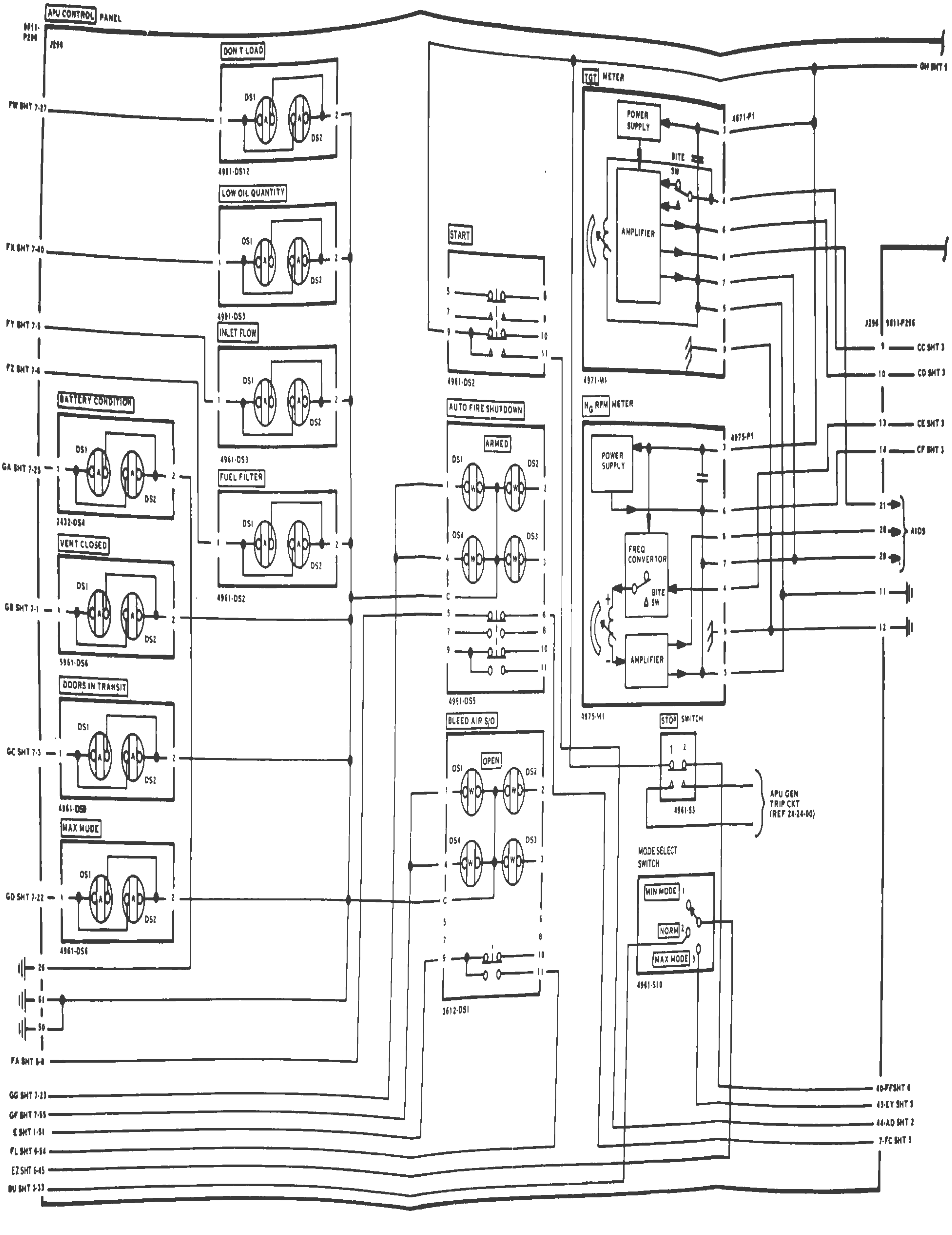
APU AND ELECTRONIC CONTROL SYSTEM SCHEMATIC
FIGURE 4-5 (Sheet 5 of 9)



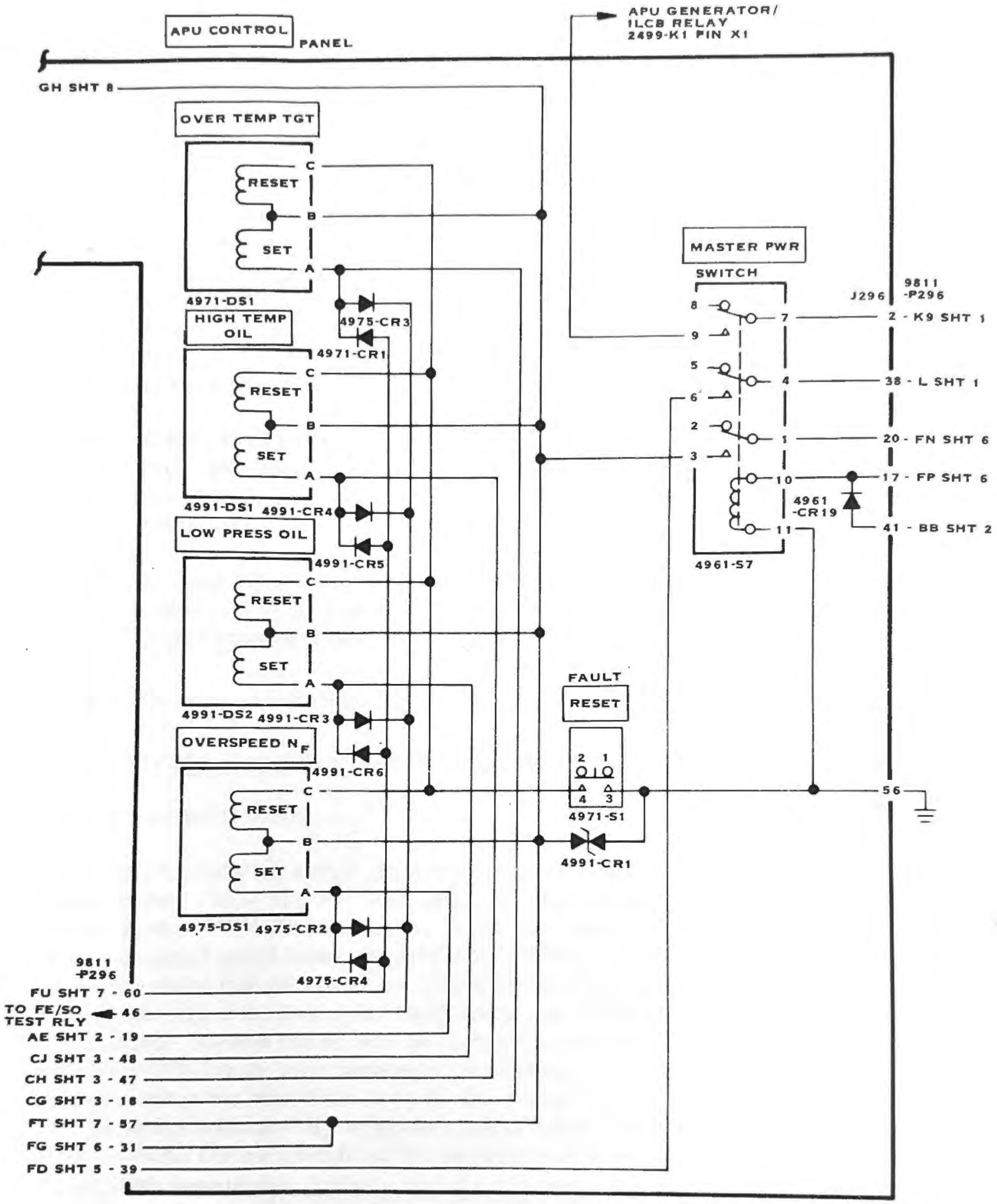
APU AND ELECTRONIC CONTROL SYSTEM SCHEMATIC
FIGURE 4-5 (Sheet 6 of 9)



APU AND ELECTRONIC CONTROL SYSTEM SCHEMATIC
FIGURE 4-5 (Sheet 7 of 9)



APU AND ELECTRONIC CONTROL SYSTEM SCHEMATIC
FIGURE 4-5 (Sheet 8 of 9)



APU AND ELECTRONIC CONTROL SYSTEM SCHEMATIC
FIGURE 4-5 (Sheet 9 of 9)

CONTROLS AND INDICATORS

Controls and indicators for the APU control system are contained mainly on the APU CONTROL panel and the external APU control panel (Reference Figure 4-2). In addition, the electronic control system contains the following indicators mounted at other locations in the aircraft.

- APU emergency shutoff indicator lights located on the Flight Engineer/ Second Officer's FUEL CONTROL panel. The indicator lights on the FUEL CONTROL panel divide into two sections, with the legends PRI and SEC. The sections connect to the limit switches of the primary and secondary firewall shutoff valves, and act as valve-in-transit lights. Each light comes ON during the time that the valve changes position. The light goes OFF as soon as the valve reaches the desired position. Normal in-transit time is approximately two seconds.

- ENG/APU STATUS legend indicators located on the Pilot's MASTER CAUTION panel on the Pilot's Center Instrument Panel. The indicator illuminates when any one of the four fault flags is tripped by the APU Electronic Controller.

- Elapsed Time Indicator located on the forward right side of the APU engine. The indicator is a digital counter which displays hours of APU engine running time.

- ΔP Switch located next to the P3 air filter.

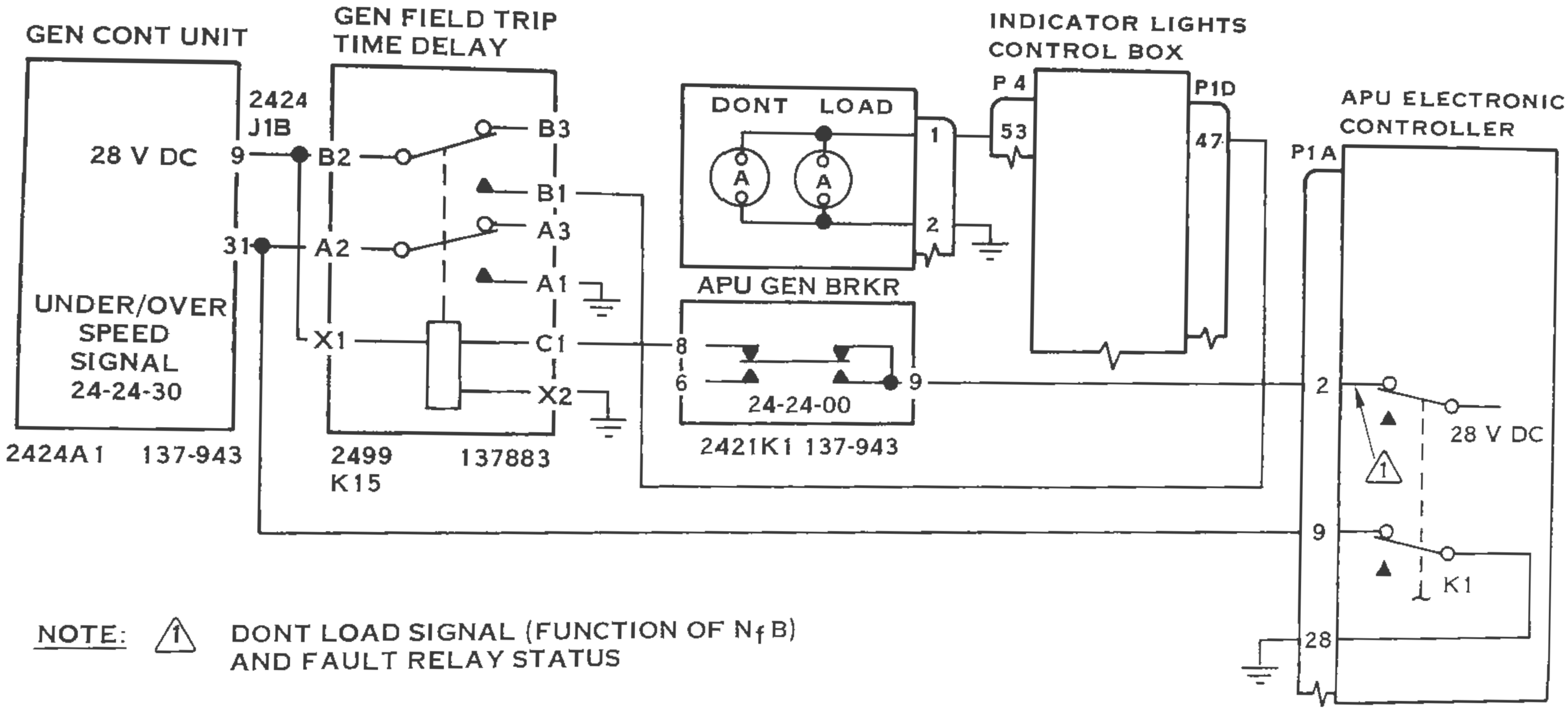
APU CONTROL Panel (Reference Figure 4-2)

MASTER POWER Switch

The MASTER POWER switch (Reference Figures 4-12) is an electrically latching toggle switch whose function is to apply dc voltage from the continuous power circuit to the APU control circuits. When the switch is selected to the ON position, contacts 4 and 6 cause the APU BAT PWR RCCB to energize, thus providing aircraft battery bus voltage at the output of the continuous power circuit. This voltage energizes the hold coil, maintaining the MASTER POWER switch in the ON position. Master power may be turned OFF by manually selecting the switch to OFF, or by interruption of the holding coil voltage. During APU operation after the inlet door is open, the Master Power Reset relay maintains voltage on the holding coil, so master power cannot be interrupted by operation of the POWER ON switchlight on the external APU control panel. When the APU engine inlet door closes during a normal shutdown, the Master Power Reset relay deenergizes, and master power may then be interrupted by the POWER ON switchlight on the external APU control panel.

START Switch and DONT START Indicator

The START Switch (Reference Figure 4-13) is a momentary switchlight which initiates the APU start cycle by energizing the Start relay.



DONT LOAD INDICATOR
CIRCUITS FUNCTIONAL DIAGRAM
(A/C 1038 and later)
FIGURE 4-6

STOP Button

The STOP button is a momentary pushbutton switch which initiates the APU shutdown cycle by interrupting latching voltage to the Stop relay. (Reference Figure 4-13.) This switch also provides a signal to the generator control unit to trip the APU generator off the line.

AUTO FIRE SHUTDOWN Switchlight

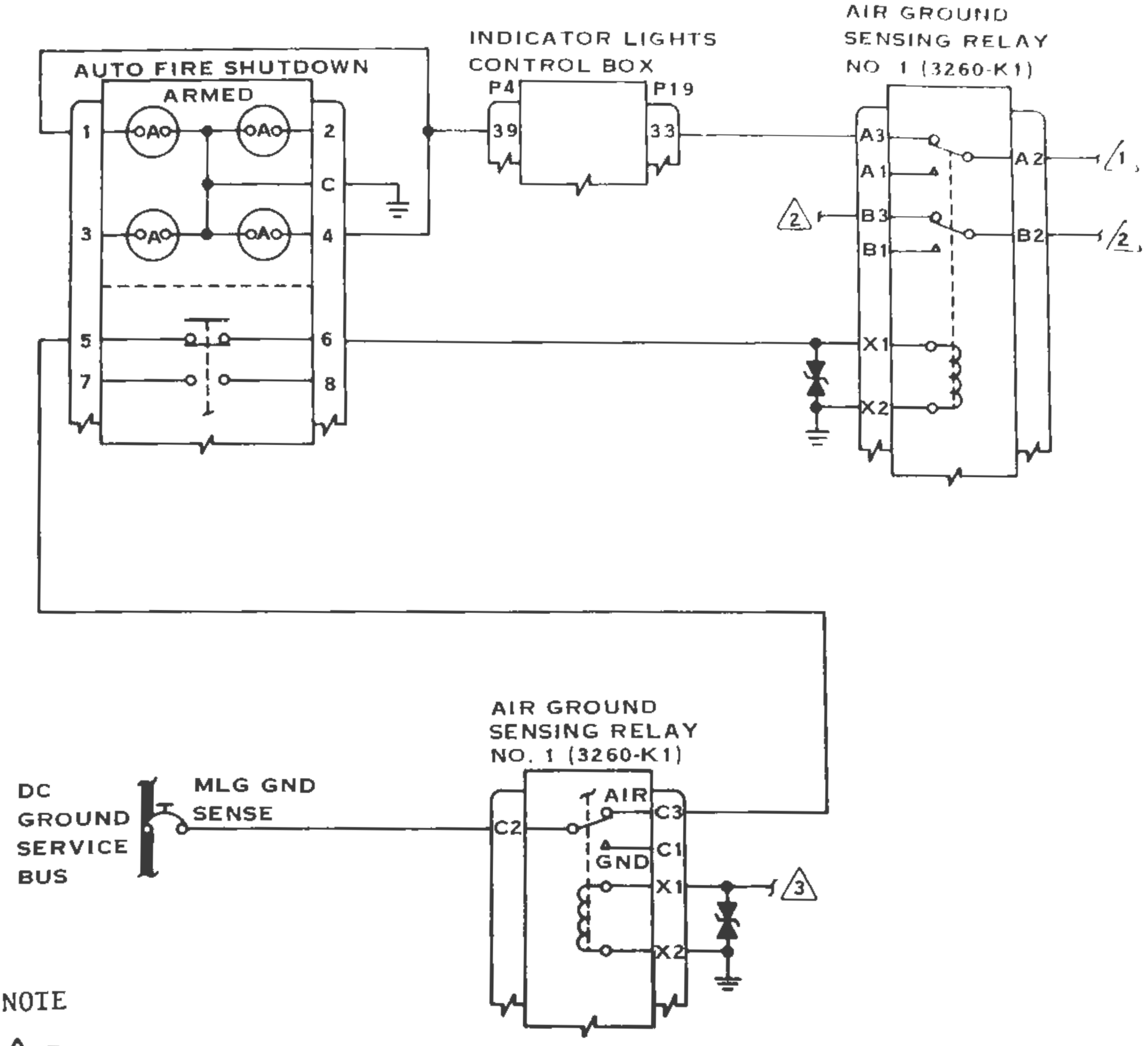
The function of this switch (Figure 4-7) is to arm the circuit which initiates automatic APU shutdown when the fire detector senses a fire in the APU compartment. With the aircraft on the ground, the APU Shutdown Mode relay is deenergized and the fire detector is armed. When in flight, the fire detector is armed only if the AUTO FIRE SHUTDOWN switchlight is released. When either of these conditions exist, the ARMED legend of the switchlight is illuminated and if a fire is detected, the fire detector will energize Auto Fire Shutdown Relays No. 1 and No. 2. In flight, the automatic fire shutdown function can be disarmed by pressing and latching the AUTO FIRE SHUTDOWN switchlight. The APU Shutdown Mode relay energizes and the ARMED legend goes OFF.

BLEED AIR S/O Switchlight (APU Isolation Valve)

The BLEED AIR S/O switchlight (Reference Figure 4-23) controls the APU isolation valve which interlocks with the inlet guide vane control mode. When the switchlight is unlatched, voltage to the APU isolation valve is interrupted and the valve is forced to close, isolating APU load compressor air from the pneumatic system. Also, the closed valve limit switch prevents energizing the IGV Mode Select relay to normal position (and holds it in MIN) causing the APU Electronic Controller to operate in MIN MODE and disabling the load compressor mode switch and Engine Start relay inputs. When the switchlight is pressed and latched, the APU isolation valve solenoid is energized if the APU Inlet Door relays are latched in. Pneumatic pressure then opens the valve, closing a limit switch that causes the OPEN legend to illuminate and also arms the IGV mode select relay. With the valve open, the pneumatic system is supplied with APU load compressor air and the load compressor mode switch and main engine ground start relay circuits are armed so that the APU Electronic Controller can then operate in the selected mode (MIN, NORM or MAX).

Load Compressor Mode Switch

The load compressor mode switch (Reference Figure 4-23) allows manual selection of the inlet guide vane (IGV) control mode. However, when the bleed air shutoff valve is closed, the APU Electronic Controller can only operate in MIN MODE. When the switchlight is pressed and latched and the valve is open



NOTE

1. FROM CONTINUOUS POWER CIRCUIT
2. SEE FIRE DETECTION CIRCUITS
3. ENERGIZED ON GROUND

APU AUTO FIRE SHUTDOWN INDICATOR FUNCTIONAL DIAGRAM
FIGURE 4-7

the load compressor mode switch can select either MIN MODE, NORM or MAX MODE. Starter relay operation during a main engine ground start causes the IGV Max Select relay to energize, overriding the mode switch and providing a MAX MODE command to the APU Electronic Controller. However, the function is disabled if the bleed air shutoff valve is not open. The MAX MODE indicator above the mode switch illuminates through contacts in the IGV Max Select relay. The MAX mode position is momentary and control mode will return to NORM mode when the switch is released or the main engine start relay drops out.

Indicator Lights

Eight indicator lights located on the APU CONTROL panel provide APU operational status information.

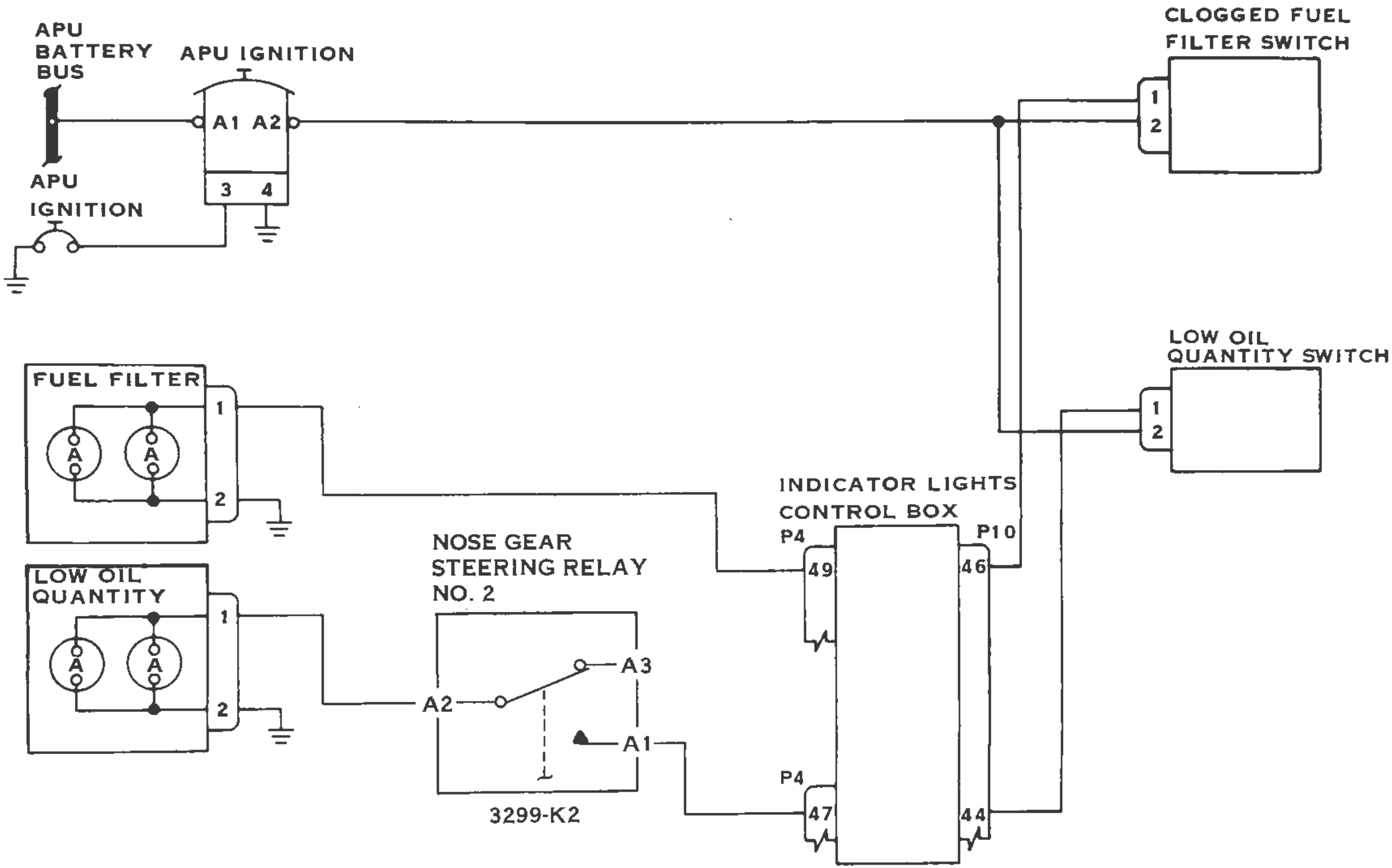
DONT LOAD Light (Reference Figure 4-6) - illuminates when power is first applied to the APU Electronic Controller and remains on during the APU start until N_f exceeds 95%. After passing 95% N_f the DONT LOAD light will illuminate whenever N_f exceeds 105% or whenever N_f drops below 90% or if the fault relay is energized. The DONT LOAD indicator receives a signal (through the indicator light control box) from the generator field trip time delay relay, which also signals the generator control unit to trip the APU ac generator on or off the line. The generator field trip time delay relay receives a command signal from the APU Electronic Controller if the APU generator breaker is not tripped.

BATTERY CONDITION Light - illuminates when the battery charger senses overtemperature or a shorted cell. The indicator is a component of the battery system, but is located on the APU CONTROL panel since APU start is a critical battery load.

VENT CLOSED Light (Reference Figure 4-14) - illuminates through limit switch closure in the APU vent air exhaust valve. The APU vent air exhaust valve is open under normal operating conditions, and is commanded closed only by an automatic fire shutdown or by operation of one of the FIRE PULL handles.

DOORS IN TRANSIT Light (Reference Figure 4-15) - illuminates when either the APU engine inlet door or the vent ejector door is not in the position called for by the APU Inlet Door relays. Normally, the light illuminates for 10 to 12 seconds when the doors are in transit during the start cycle and shutdown cycle. If the light remains on continuously the door systems or indicator light are malfunctioning.

INLET FLOW LIGHT (Reference Figure 4-21) - illuminates when an automatic protective shutdown due to an abnormal pressure drop in the load compressor inlet duct occurs. The light is supplied with 28 Vdc power when the inlet flow shut-down relay is energized by a 28 Vdc signal from the APU Electronic Controller whenever the ΔP switch is energized. This function is disabled through the IGV MAX select relay contacts when operation in MAX MODE occurs. Actuation of the ΔP Switch in NORM or MIN mode energizes the inlet flow shutdown relay which deenergizes the APU stop relay to cause the APU Electronic Controller to process through a normal stop cycle, closing the inlet and vent-ejector doors.



FUEL AND OIL INDICATOR CIRCUITS FUNCTIONAL DIAGRAM
FIGURE 4-8

FUEL FILTER Light (Reference Figure 4-8) - illuminates when master power is ON and the clogged fuel filter switch closes due to differential pressure across the APU engine fuel filter exceeding 1.25 psi.

LOW OIL QUANTITY Light (Reference Figure 4-8) - illuminates when master power is ON and a float switch in the APU engine oil tank senses an oil level below the minimum quantity. To prevent the low oil quantity light from coming on in flight, it is wired through the No. 2 nose gear steering relay.

MAX MODE Light (Reference Figure 4-23) - illuminates whenever the IGV Max Mode relay is energized.

Fault Flags

The APU CONTROL panel also contains four latching fault flags (Figure 4-9) which display the cause of an automatic shutdown initiated by the APU Electronic Controller.

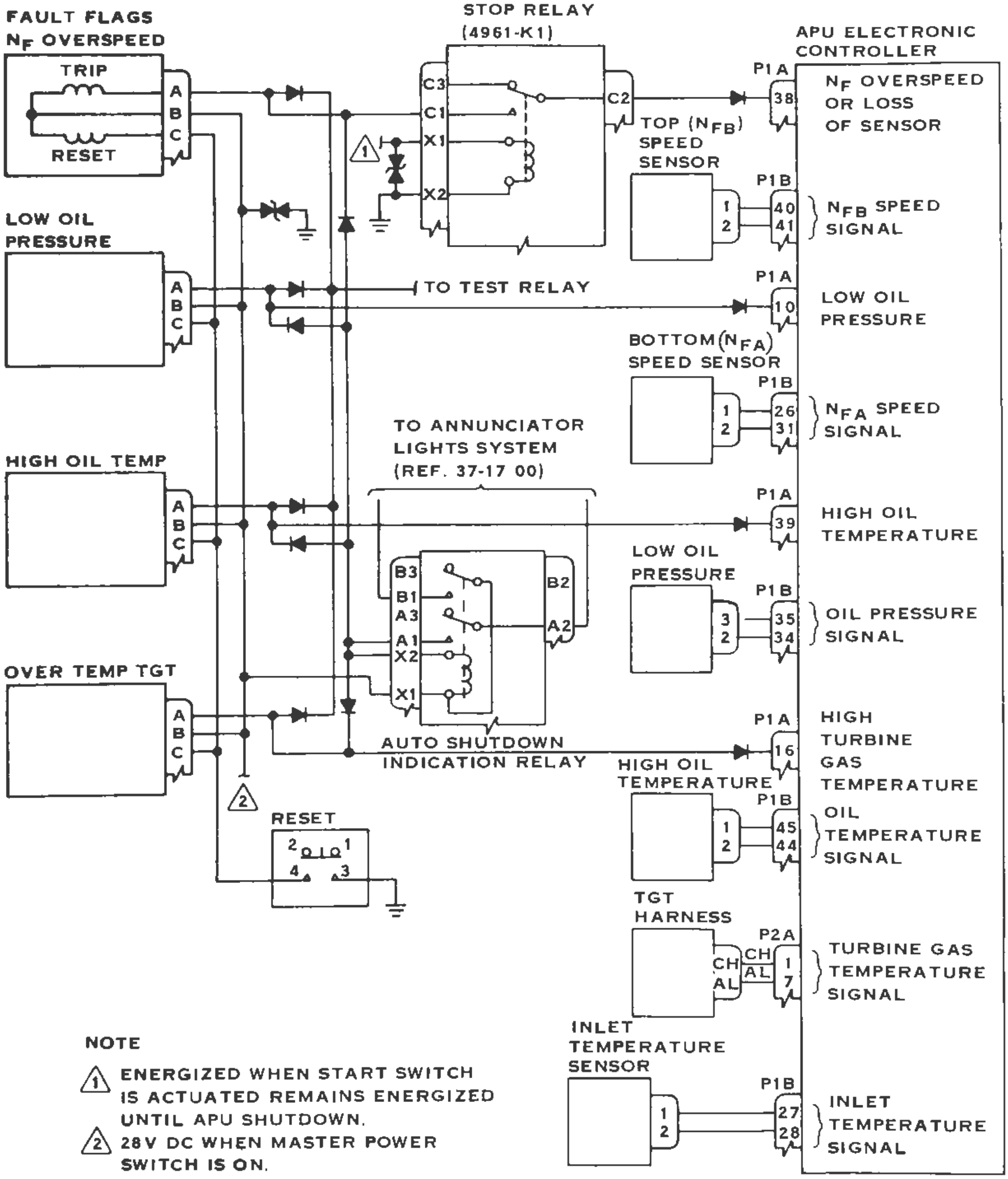
- OVERSPEED N_f
- LOW PRESS OIL
- HIGH TEMP OIL
- OVERTEMP TGT

Each fault flag indicator consists of a magnetic flag, a trip coil and a reset coil. When the trip coil is energized by the APU Electronic Controller, the flag appears in a window of the indicator and remains until the reset coil is energized with the RESET button. Reset can only be accomplished with the MASTER POWER switch ON. The trip coils are connected through diodes to the Auto Shutdown Indication relay so that a trip voltage to any one flag also energizes the relay. The relay causes the ENG/APU STATUS annunciator to illuminate on the Pilot's center console. Since a normal shutdown is triggered by a simulated N_f overspeed signal, the signal path is disabled by the Stop relay on a normal shutdown, to prevent tripping the N_f OVERSPEED fault flag. The Nf OVERSPEED fault flag will also be tripped if the NfA sensor is interrupted.

Percent Ng RPM Indicator (Figure 4-10)

The %N_g RPM indicator on the APU CONTROL panel displays the gas generator (N_g) rpm in percent. There is no display of the free (power) turbine (N_f) rpm which is normally controlled to a constant value. However, ac generator frequency and PMG voltage provide a good indication of N_f, if desired.

The rpm indication system consists of a gas generator (N_g) tachometer mounted on the APU engine accessory case, signal conditioning circuitry in the APU Electronic Controller, and the % N_g RPM indicator mounted in the APU CONTROL panel. The APU Electronic Controller also utilizes the gas generator tachometer (N_g) signal for control of N_g and N_f speed to maintain a constant generator frequency while also maintaining the APU engine operation within desirable limits.



FAULT FLAG CIRCUIT FUNCTIONAL DIAGRAM
FIGURE 4-9

In the event of electrical power loss to the APU Electronic Controller, or interruption of the Ng tach generator signal, the % Ng RPM indicator will immediately drop to zero regardless of the actual N_g level. During other engine protection shut downs or normal shutdowns, the engine will have coasted down prior to removal of MASTER POWER. The % Ng RPM indicator converts a positive five volt variable frequency square wave signal from the APU Electronic Controller into a visual indication of % Ng rpm. The indicator face is graduated in 5% steps and has a green normal operation band from 55% to 105%. A red radial warning mark accents the 105% level. An APU gas generator speed of 37,500 rpm is indicated as 100%. Manually pressing a BITE switch in the lower left corner of the indicator will provide a check of indicator operation by driving the indicator to approximately 100% if functioning properly. MASTER POWER must be ON for the BITE switch to function.

TGT Indicator (Figure 4-11)

The TGT indicator mounted in the APU CONTROL panel, provides indication of engine operating temperature. Four double Chromel/Alumel thermocouple probes connected together by braided cables form a single integral T_1, T_3, T_7 temperature sensing harness that provides TGT signals to the APU Electronic Controller. The APU Electronic Controller conditions the simulated temperature signal for internal use to control the APU engine so that TGT operational limits are not exceeded and also to provide a current signal proportional to actual TGT, to the TGT indicator.

The turbine gas temperature indicator is a permanent magnet moving-coil type of electrical indicating instrument. The scale is graduated from 0 to 12 and reads in hundreds of degrees C. A green normal operation band extends from 450 degrees to 1065 degrees. A red warning band extends from 1065 degrees to the end of the scale. Manually pressing a BITE (Built In Test Equipment) switch in the lower left corner of the indicator, will provide a check of indicator operation by driving the indicator to approximately 1100°C, if functioning properly. The MASTER POWER switch must be ON for the BITE switch to function.

External APU Control Panel

POWER ON Switchlight (Reference Figures 4-12)

When illuminated, the POWER ON switchlight legend provides an indication that the MASTER POWER switch on the main APU CONTROL panel is on. The normally closed switchlight contacts provide temporary latching voltage to the MASTER POWER switch by energizing the MASTER POWER switch hold coil. The POWER ON switchlight allows master power to be turned off from the external APU CONTROL panel. The Master Power Reset relay provides the primary latching path, so interruption of master power by use of the POWER ON switchlight is only possible when the Master Power Reset relay is deenergized. During the start cycle, this relay is energized when the APU engine

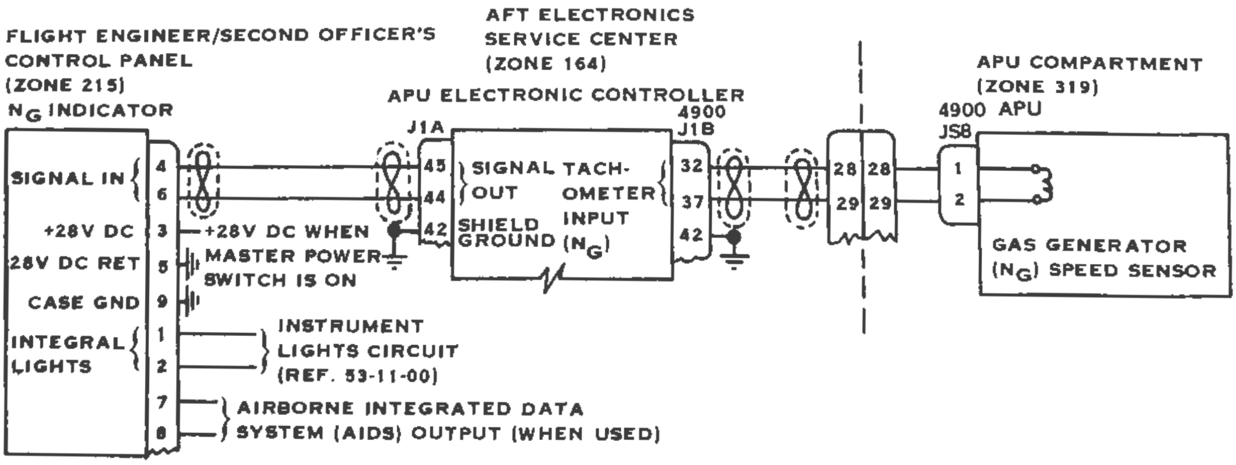
inlet door opens, and deenergizes on shutdown when the APU engine door closes, preventing inadvertent interruption of master power from the external APU control panel until the shutdown sequence is complete.

NORM STOP Button (Switch) (Reference Figure 4-13)

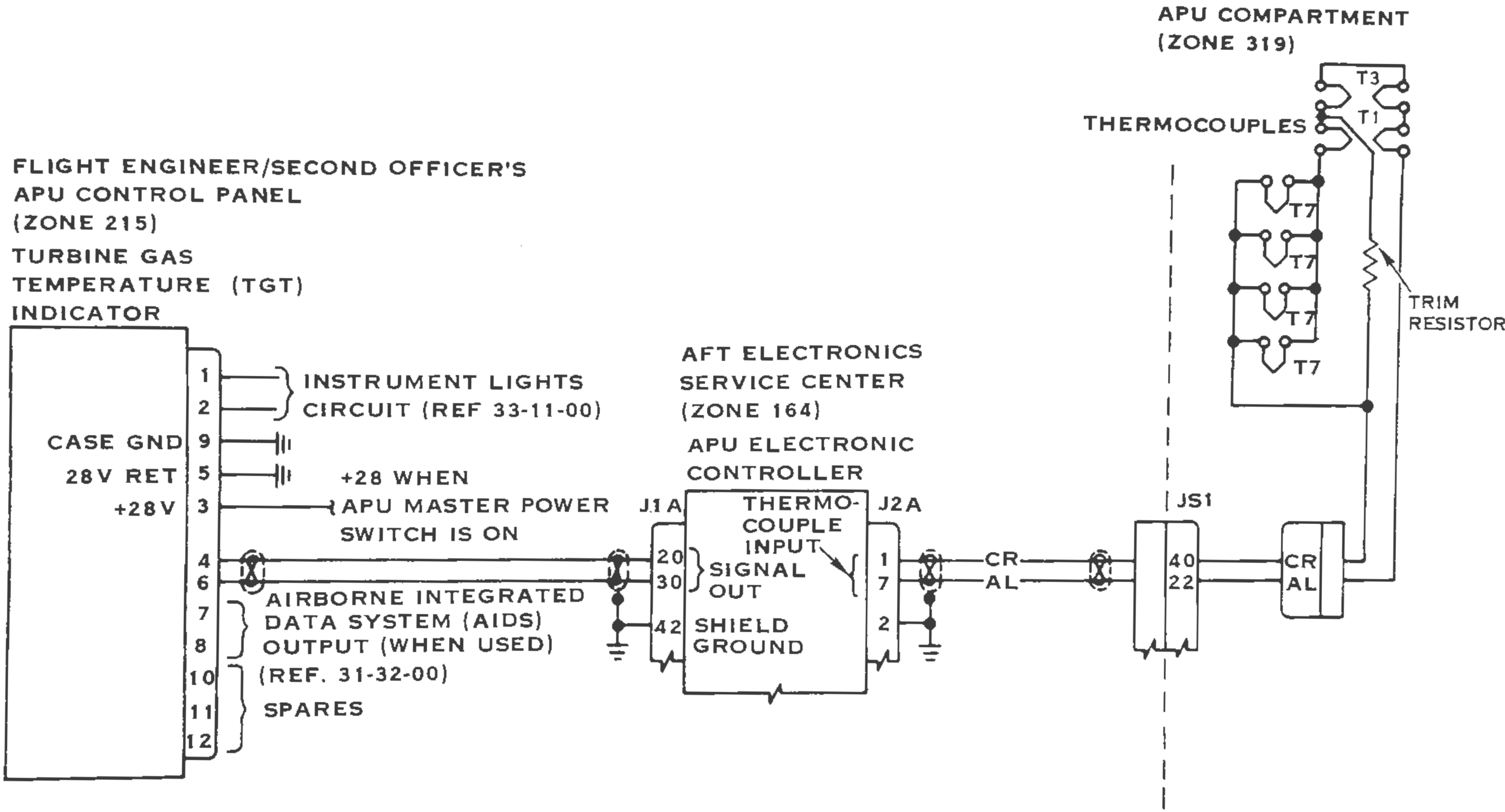
Pressing the NORM STOP button will result in a manual shutdown of the APU from the external APU control panel. The switch is electrically connected in series with the STOP button on the internal APU CONTROL panel, therefore the same shutdown sequence is initiated by both stop buttons.

FIRE PULL Handles

Pulling a FIRE PULL handle will initiate a fire shutdown by interrupting latching voltage to the Stop relay and Inlet Door relays. (Reference Figure 4-13). Other fire shutdown functions are similar to those for an automatic fire shutdown described later.



% Ng INDICATING CIRCUIT-SYSTEM FUNCTIONAL DIAGRAM
FIGURE 4-10



TGT INDICATING SYSTEM FUNCTIONAL DIAGRAM
FIGURE 4-11

POWER CIRCUITS

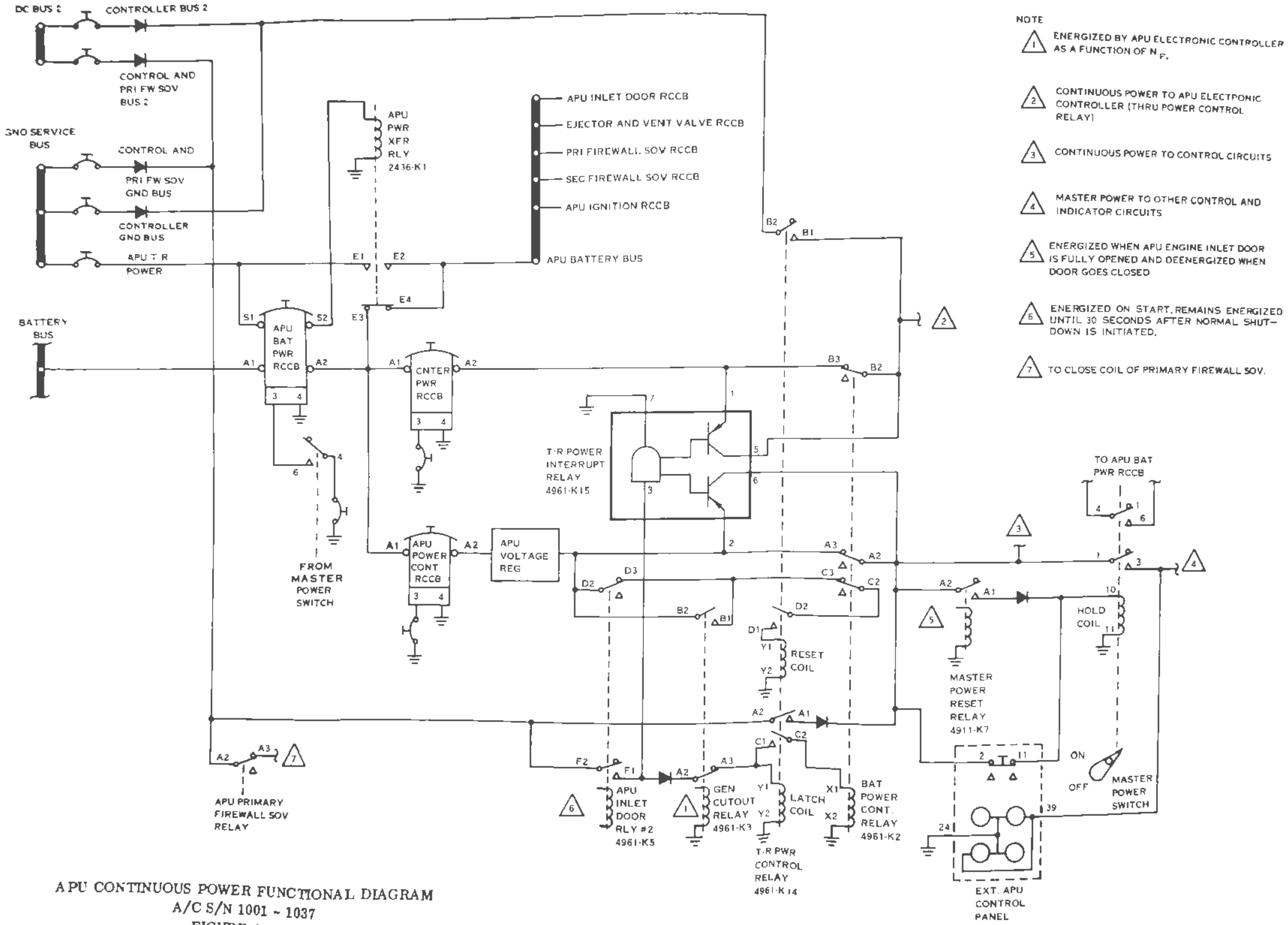
The power circuits (Figures 4-12) supply and control power to the APU CONTROL SYSTEM. Three power sources, the aircraft battery bus, the dc ground service bus, and the dc bus 2, supply power to the APU battery bus and the continuous power circuit. Some of the controlling logic for the power circuits is shown on the start and stop control diagram Figure 4-13.

Continuous Power Transfer

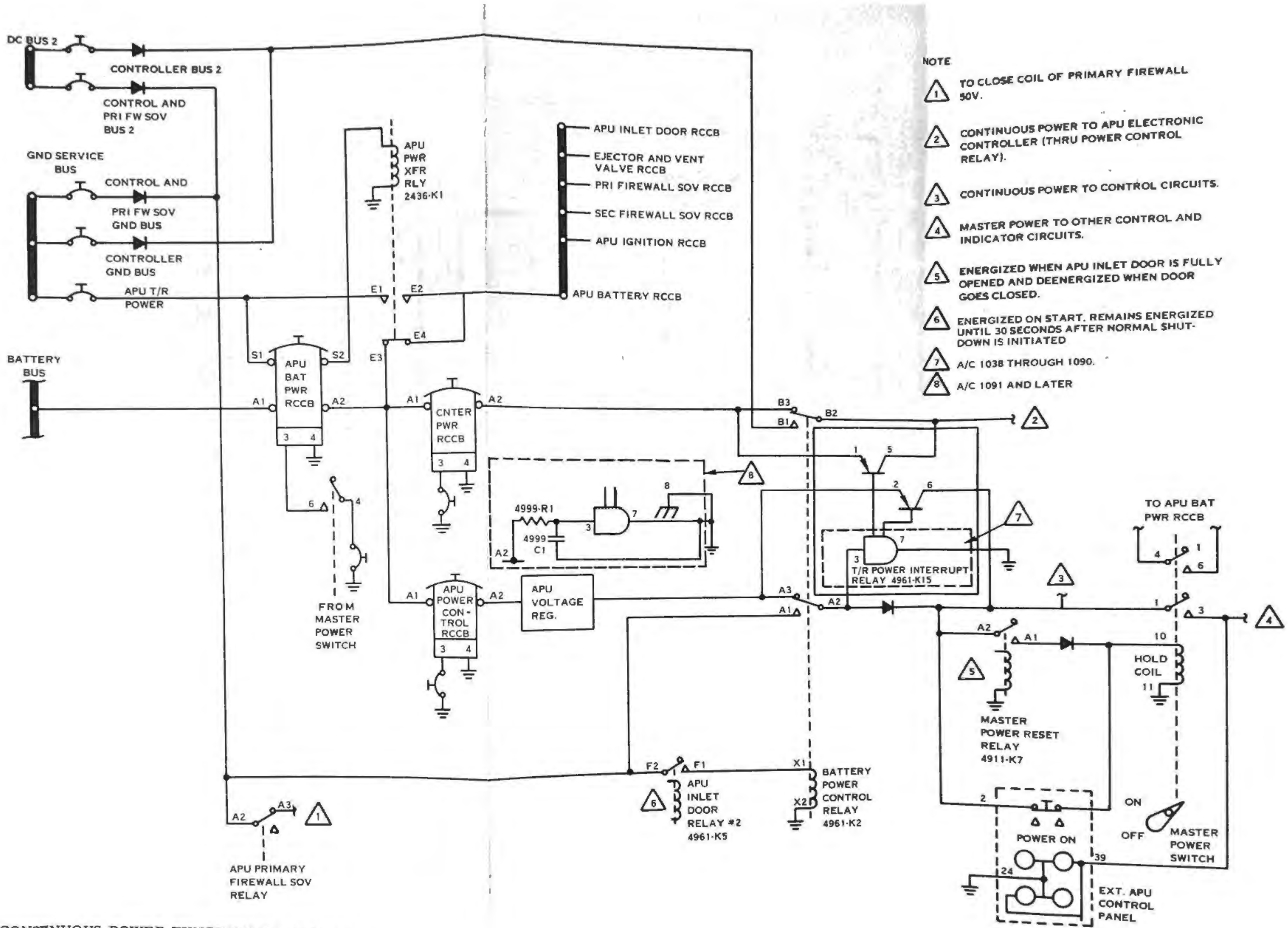
The Primary control for the power circuits is the MASTER POWER switch on the APU CONTROL panel. With this switch in the OFF position, aircraft power is disconnected from all APU control circuits except the primary firewall shutoff valve. Normally closed contacts A2 and A3 of the APU Primary Firewall Shutoff Valve relay apply power from the dc bus 2, or dc ground service bus to the close coil of the primary firewall shutoff valve.

The MASTER POWER switch controls the APU BAT PWR RCCB (remote controlled circuit breaker), which applies aircraft battery bus power to the APU continuous power circuit. The function of the APU continuous power circuit is to maintain continuous power to the APU Electronic Controller and the APU control circuits by selecting the source of continuous power from either the aircraft battery bus or the combined dc bus 2 and ground service bus (T/R power). The switching logic exists in three configurations. Aircraft serial numbers through 1037 utilize the Generator Cutout relay, T/R Power Control relay, and Battery Power Control relay to select the source of continuous power. In aircraft serial numbers 1038 and up, the Generator Cutout relay and T/R Power Control relay are deleted and transfer of continuous power is accomplished by use of the Battery Power Control relay. The function of the T/R Power interrupt relay is identical in both configurations. Aircraft S/N 1091 and later utilize an RC time delay circuit with the T/R power interrupt relay and employ the INLET FLOW shutdown control circuits. A description of the differences in the continuous power circuits logic follows.

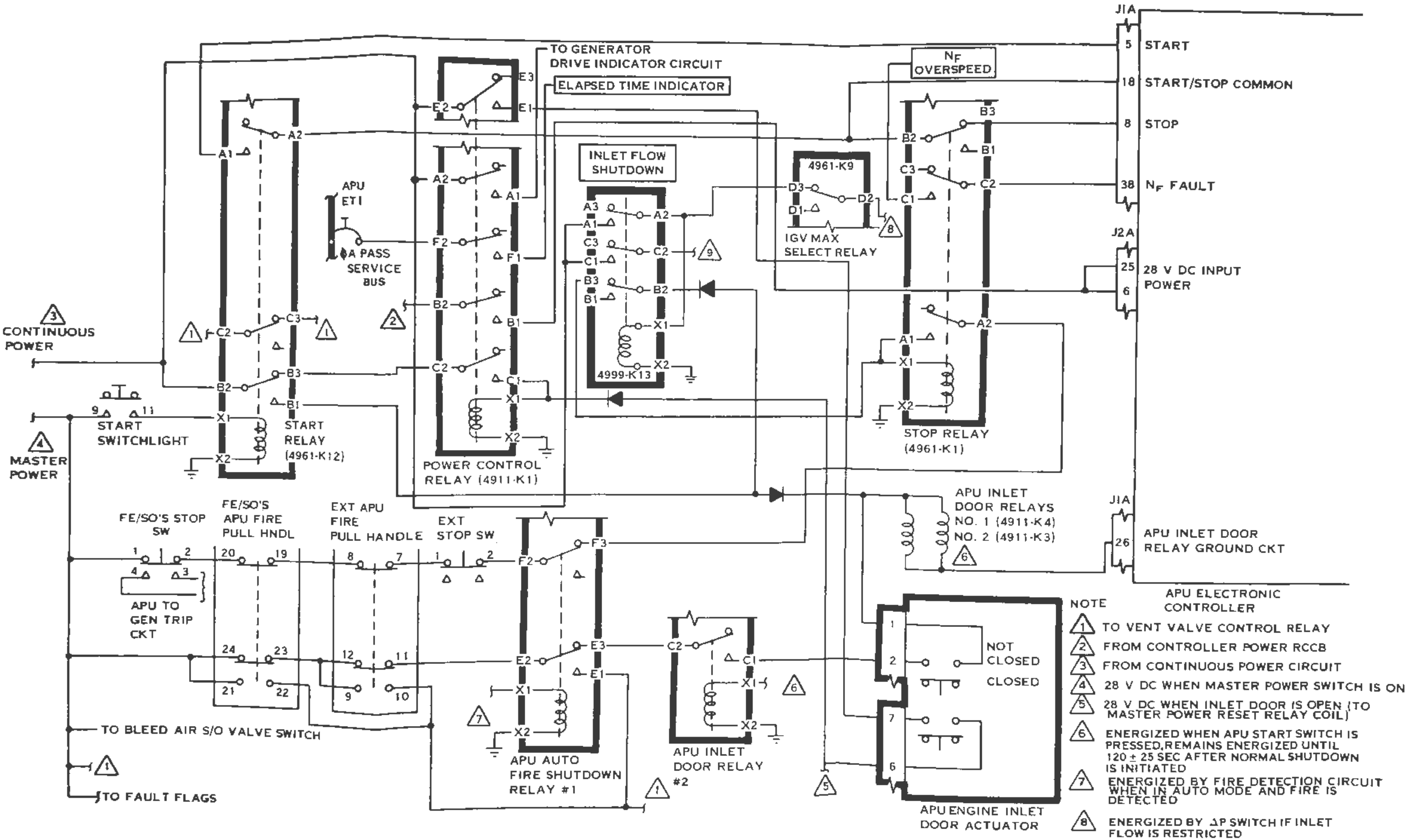
For Aircraft through S/N 1037. (Reference Figure 4-12A) When the MASTER POWER switch is selected to ON, the APU BAT PWR RCCB closes and the normally closed contacts A2 and A3 of the Battery Power Control relay apply aircraft battery bus voltage to the output of the continuous power circuit. If the T/R Power Control relay was in a latched condition with the MASTER POWER switch ON the voltage regulator output energizes the reset coil, unlatching the relay. During a normal shutdown, the reset coil is energized by the APU Electronic Controller, and continuous power is transferred to the aircraft battery bus. When the APU passes 95% N_f on start up the APU Electronic Controller deenergizes the Generator Cutout relay, which applies T/R voltage to the T/R Power Control relay. This relay latches, connecting the continuous power circuit to T/R power. Also, contacts C1 and C2 energize the Battery Power Control relay, disconnecting the continuous power circuit from the aircraft battery bus. On shutdown, the Generator Cutout relay is energized, causing the Battery Power



APU CONTINUOUS POWER FUNCTIONAL DIAGRAM
A/C S/N 1001 - 1037
FIGURE 4-12A



APU CONTINUOUS POWER FUNCTIONAL DIAGRAM
A/C S/N 1038 UP
FIGURE 4-12B



START AND STOP CONTROL FUNCTIONAL DIAGRAM
FIGURE 4-13

Control relay to deenergize. Contacts C2 and C3 reset the T/R Power Control relay, completing transfer of continuous power to the aircraft battery bus.

For Aircraft S/N 1038 and up. (Reference Figure 4-12B) The deletion of the Generator Cutout relay and the T/R Power Control relay simplifies the continuous power transfer logic. Whenever the APU Engine Inlet Door relays energize, the Battery Power Control relay energizes and transfers continuous power from the aircraft battery bus to T/R Power (if it is available). During a normal start the APU Inlet Door relays energize when the START switchlight is pressed. On shutdown, the relays remain latched for 120± 25 seconds after the STOP button is pressed, until the APU Electronic Controller removes the ground from the APU Engine Inlet Door relays, and continuous power transfers from T/R power to the aircraft battery bus.

For aircraft S/N 1091 and later an RC time delay circuit is added in the T/R power interrupt relay control line to eliminate nuisance power interrupt shutdowns. Also the INLET FLOW shutdown control circuits are added.

APU Battery Bus Transfer

The continuous power circuit also controls transfer of the APU battery bus. The APU Power Transfer relay controls which aircraft bus feeds the APU battery bus. The relay is normally deenergized and connects the aircraft battery bus to the APU battery bus through the APU BAT PWR RCCB. When the APU MASTER POWER switch is turned ON, auxiliary contacts in the BAT PWR RCCB supply T/R power to the APU power transfer relay coil which transfers the ground service bus directly to the APU battery bus.

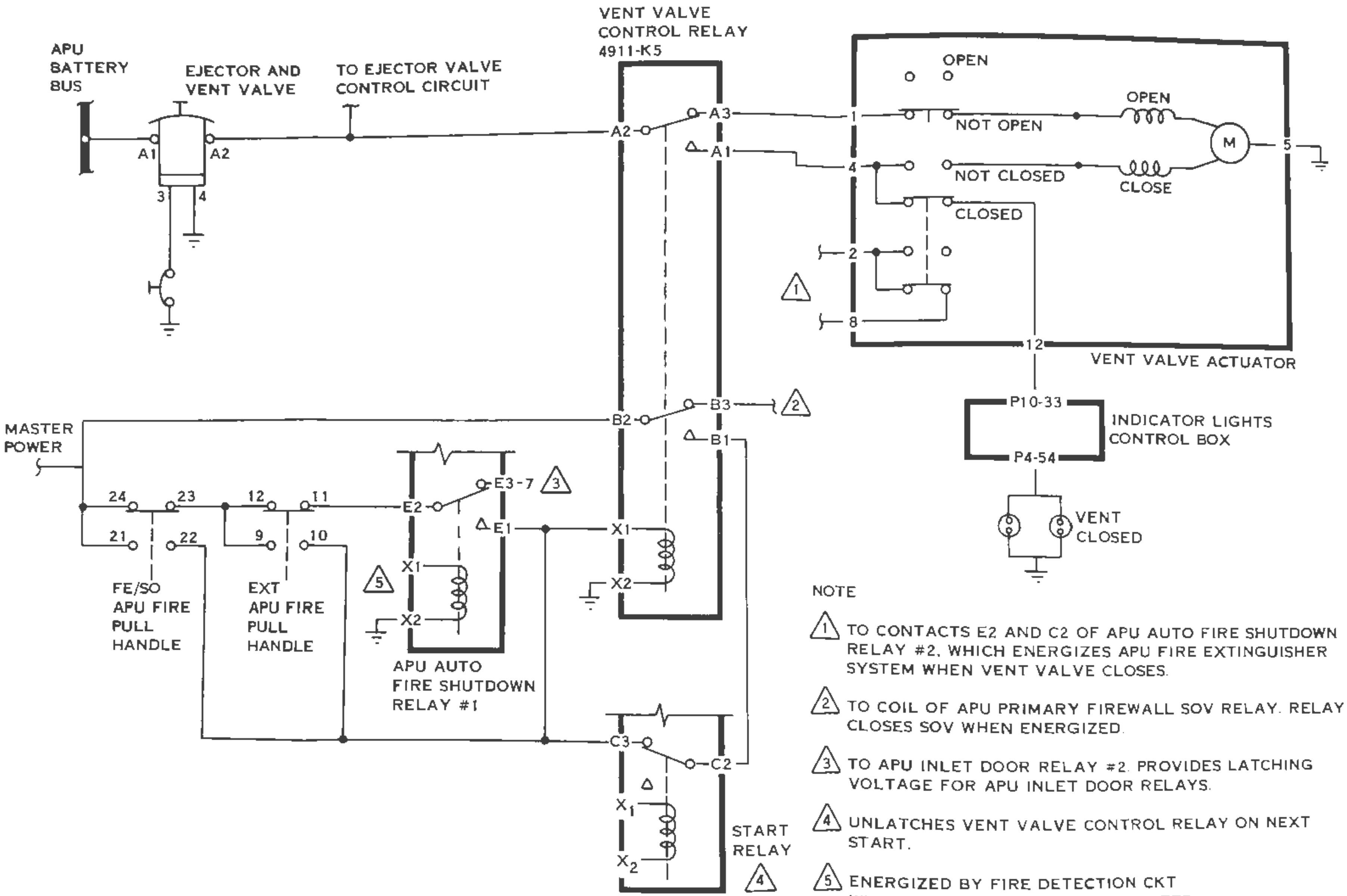
Power Interrupt

An abnormal condition can occur when the APU ac generator is the only power source, other than the battery, and the generator is deenergized with the APU running. Shutting the generator down will deenergize the transformer/rectifiers and the dc buses. Loss of dc bus power will cause an interruption of the continuous power and shut down the APU. To reduce the possiblity of this happening, an extremely rapid action electronic T/R Power Interrupt relay is utilized to sense the dc bus power. The transistor switches of this relay are in parallel with the power switching contacts of the Battery Power Control relay. In the event of bus power loss, the T/R Power Interrupt relay deenergizes and connects the battery power to the continuous power circuits before the normal transfer circuit has time to operate (within 25 microseconds).

Logic Description

NOTE: The following is a detailed description of the power circuit logic resulting from turn-on of the MASTER POWER switch. This description assumes that the aircraft has electrical power turned on and therefore the T/R 28V dc is available.

When the MASTER POWER switch is selected ON, (Reference Figures 4-12), and its contacts 4 and 6 close, closing the APU BAT PWR RCCB, continuous power from the aircraft battery bus is now available through APU power control RCCB and the following events take place:



NOTE

1. TO CONTACTS E2 AND C2 OF APU AUTO FIRE SHUTDOWN RELAY #2, WHICH ENERGIZES APU FIRE EXTINGUISHER SYSTEM WHEN VENT VALVE CLOSES.
2. TO COIL OF APU PRIMARY FIREWALL SOV RELAY. RELAY CLOSES SOV WHEN ENERGIZED.
3. TO APU INLET DOOR RELAY #2. PROVIDES LATCHING VOLTAGE FOR APU INLET DOOR RELAYS.
4. UNLATCHES VENT VALVE CONTROL RELAY ON NEXT START.
5. ENERGIZED BY FIRE DETECTION CKT WHEN IN AUTO AND FIRE IS DETECTED.

VENT AIR EXHAUST VALVE CONTROL
FUNCTIONAL DIAGRAM
FIGURE 4-14

- The hold coil of the MASTER POWER switch is energized.

- Aircraft T/R bus power is applied to the APU battery bus by the energized APU Power Transfer relay (Energized through contacts S_1 and S_2 of APU BAT PWR RCCB). This arms the LOW OIL QUANTITY and FUEL FILTER indicators on the APU CONTROL panel. It also arms the APU and A/C INLET FLOW shutdown circuits.

- The vent air exhaust valve is commanded open (if previously closed) by APU battery bus voltage through the deenergized Vent Valve Control relay (Figure 4-14). The vent air exhaust valve is normally always open and closes only on a fire handle pull or auto fire shutdown.

- A close command is applied to the vent ejector through the deenergized APU Engine Inlet Door relay #2. If the previous APU shutdown was out of sequence, the DOORS IN TRANSIT indicator light may come on while the vent ejector slews closed.

When the MASTER POWER switch contacts 1 and 3 close, continuous power is connected to the master power distribution and the following events take place:

- The POWER ON (indicator segment) legend of the switchlight is energized on the external APU control panel. If the momentary POWER ON switchlight is inadvertently pressed at this point (and up until the APU engine Inlet Door is full open), the MASTER POWER switch hold coil will deenergize, removing master power. When the APU engine Inlet Door reaches the full open position, the hold coil is latched by the Master Power Reset relay, so that inadvertent operation of the POWER ON switchlight on the external APU control panel will not affect APU operation.

- The primary firewall shutoff valve is commanded open (if previously closed). As the valve slews from closed toward open, the emergency shutoff indicator on the Fuel System Panel illuminates the PRI legend, indicating that the valve is in transit. The valve slews rapidly, and the PRI legend only remains illuminated for approximately one second. This valve normally opens and closes with the MASTER POWER switch position. However, it will not close if T/R power is not available. The primary firewall shutoff valve is opened by master power applied through normally closed contacts B2 and B3 of the Vent Valve Control relay (Reference Figure 4-14). This energizes the APU Primary Firewall Shutoff Valve relay, which applies APU battery bus power from the Firewall Shutoff Primary RCCB to the open coil of the primary firewall SOV.

- Master power is applied through the bleed air shutoff valve system (if valve is not open, the IGV Mode Select relay is disabled which maintains a MIN MODE command to the APU Electronic Controller) (Reference Figure 4-23). The APU Electronic Controller, when powered by the Power Control relay after the APU engine door is full open, will automatically schedule MIN MODE. After the APU is running and the BLEED AIR S/O switchlight is pressed and latched in, opening the bleed air shutoff valve, the IGV Mode Select relay may be controlled by the position of the mode select switch (NORM or MIN MODE). Also, the IGV MAX Select relay may now be commanded to energize, overriding the IGV Mode Select relay, by holding the Compressor Mode Select switch in the MAX MODE position or by engaging an Engine Ground Start relay.

START SEQUENCE

The start sequence is manually initiated by operation of the momentary START switchlight (Reference Figure 4-13). The Start relay simultaneously energizes the Stop relay, which latches, and the two APU Engine Inlet Door relays. These relays provide open commands to the APU engine inlet door, vent ejector door, and secondary firewall shutoff valve. Note that the secondary firewall shutoff valve is normally open and will only be closed if the firewall shutdown circuitry was previously energized. The DOORS IN TRANSIT indicator light comes on as the APU engine inlet door moves off the closed stop and the APU Inlet Door relays latch.

When the APU engine inlet door reaches full open (in approximately 10 seconds) the start sequence then resumes automatically. The APU engine inlet door open limit switch energizes the Power Control relay which applies power to the APU Electronic Controller and arms the APU elapsed time indicator. The APU Electroni Controller sequencer then initiates the engine start sequence and, when the free turbine speed passes 95 percent N_f, the APU Electronic Controller transfers from starting (sequenced) control to automatic governing (steady state) control of the APU engine.

When the START button is held in (momentary switch), the Start relay energizes. The START button must be held long enough for the APU engine inlet door to move off the closed stop (approximately two seconds) so that the limit switch causes the APU Inlet Door relays to latch.

Start Relay Operation

When the START button is pushed, the Start relay is energized and the following events occur:

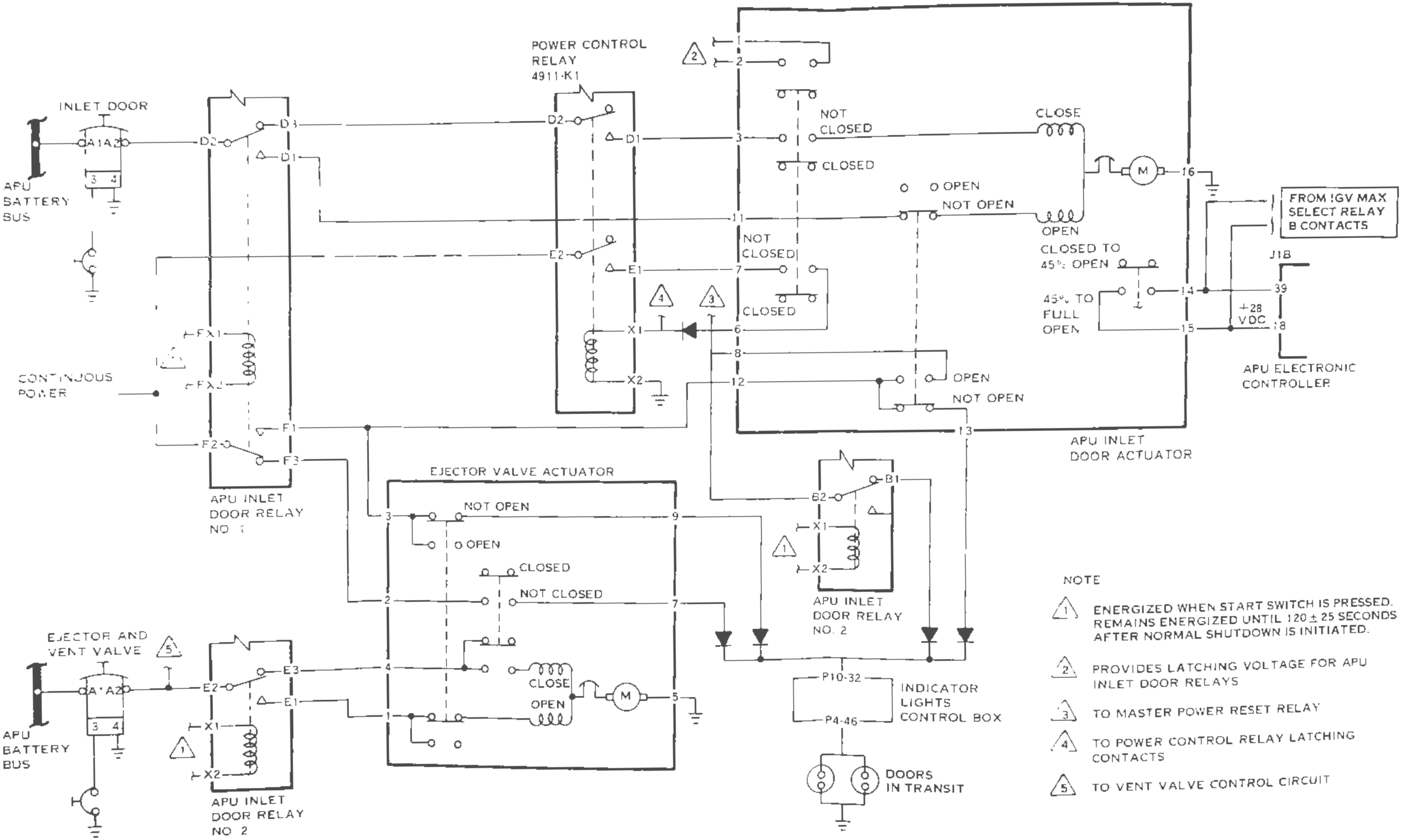
- Start enable command to the APU Electronic Controller is supplied by Contacts A1 and A2. This resets timing circuits in the APU Electronic Controller sequencer (by providing a discharge path to ground for the timing capacitors).

- Stop relay is energized (Contacts B1 and B2 close).

  - Stop relay latches, through closure of contacts A1 and A2, with master power (through the STOP button FIRE PULL handles APU Auto Fire Shutdown relay 1 and INLET FLOW shutdown relay).

  - Stop command to the APU Electronic Controller is removed by the opening of contacts B2 and B3 and the ΔP shutdown circuiting is enabled by the closing of the B2 and B1 contacts.

  - OVERSPEED N_f fault flag is armed as contacts C1 and C2 close, connecting the flag to the APU Electronic Controller (Reference Figure 4-9).



APU ENGINE INLET DOOR AND EJECTOR
VALVE CONTROL FUNCTIONAL DIAGRAM
FIGURE 4-15

APU Engine Inlet Door Relays Operation

The APU Engine Inlet Door relays 1 and 2 are simultaneously energized by closure of contacts B1 and B2 of the Start relay. The ground for these door relays is provided by the APU Electronic Controller through an internal (inlet door control) relay.

When the APU Engine Inlet Door relay 1 is energized, the following events occur:

- An open command is applied to the APU engine inlet door (APU battery bus) through contacts D1 and D2. (Figure 4-15).
- The DOORS IN TRANSIT indicator light illuminates. Continuous power is applied to the indicator lights control box through contacts F2 and F1 and the not-open limit switch contacts in both the engine inlet door actuator and the vent ejector door actuator (Reference Figure 4-15).
- An open command is applied to the secondary firewall SOV (APU battery bus through contacts A1 and A2. (Reference Figure 4-19).
- BLEED AIR S/O (APU isolation) valve is armed. (Reference Figure 4-23). Contacts B1 and B2 close, and if the bleed air S/O switchlight is in the OPEN position (actuated), 28V dc is applied to the solenoid of the bleed air shutoff (APU isolation) valve. When the S/O valve is open the IGV mode and MAX select relays are enabled. This prevents opening of the IGVs until S/O valve is opened.

When the APU Engine Inlet Door relay 2 is energized, the following events occur:

- An open command is applied to the vent ejector door actuator. Contacts E1 and E2 close, applying APU battery bus power to the actuator. (Reference Figure 4-15).
- Contacts B2 and B3 open, removing 28V dc to allow de-energizing the DOORS IN TRANSIT light when the APU engine inlet door reaches full open. (Reference Figure 4-15).
- Both APU Inlet Door relays are latched when the APU engine inlet door moves off the closed stop. (Reference Figure 4-13) The not-closed limit switch provides latching voltage from master power through contacts C1 and C2 of APU Inlet Door relay 2.

When the APU engine inlet door passes 45% open, a door malfunction switch closes to complete an enabling circuit for the APU starter control circuitry. If this switch is not closed, the APU starter cannot be energized by the APU Electronic Controller.

While the doors are in transit, the following events occur:

- If T/R power is available, system logic will transfer to that T/R power rather than battery bus as the source of continuous power. Reference Figure 4-12A and Figure 4-12B for the three configurations of continuous power circuitry. For earlier aircraft serial numbers through 1037 the Generator Cutout relay (Reference Figure 4-12A) is deenergized because power has not yet been applied to the APU Electronic Controller. This causes a temporary transfer of continuous power from the aircraft battery bus to T/R power until the APU engine inlet door reaches full open and the APU Electronic Controller is powered. This temporary transfer to T/R power and back to battery bus during the in-transit time of the APU engine inlet door does not occur on aircraft serial number 1038 and later. (Reference Figure 4-12B).

- The reset coil of the T/R power control relay is disarmed (contacts D2 and D3 open). This applies to aircraft through serial number 1037 only. (Reference Figure 4-12A).

When the APU engine inlet door reaches its full open position (Reference Figure 4-15), the following events occur:

- One pole of the limit switch in the APU engine inlet door actuator removes power from the open coil of the motor. (Similarly, when the vent ejector door reaches full open, a limit switch removes power from its open coil).

- Another pole of the open limit switch removes power from the DOORS IN TRANSIT light circuits (the light will go OFF if the APU engine inlet door and vent ejector doors are full open).

- The open limit switch also completes a circuit which applies continuous power to energize the Master Power Reset relay and the Power Control relay.

NOTE: For trouble shooting purposes, test terminals "A" and "C" in the Aft Electronic Service Center (Reference Figure 4-4, sheet 2 of 2), are available to check for proper voltage (28V dc).

When the Master Power Reset relay is energized the following events occur:

- The hold coil of the MASTER POWER switch and the Master Power relay is energized by continuous power as contacts A1 and A2 of Master Power Reset relay close (Reference Figures 4-12).

When the Power Control relay is energized (Reference Figure 4-15), the following events occur:

- The engine inlet door actuator close coil is armed as contacts D1 and D2 close.

NOTE: During the shutdown sequence, the close coil will be powered through these contacts when the APU Electronic Controller deenergizes the APU Engine Inlet Door relays.

- The Master Power Reset relay is latched through contacts E1 and E2 of the Power Control relay by continuous power through the not-closed pole of the APU engine inlet door closed limit switch. This prevents release of the MASTER POWER switch from the external APU control panel until after the engine inlet door is fully closed.

- The Power Control relay latches as contacts C1 and C2 close, applying continuous power to latch the relay coil (Reference Figure 4-13).

- The elapsed time indicator is powered as contacts F1 and F2 close, applying 115V ac, 400 Hz, phase A, to the indicator. (Reference Figure 4-13).

- Generator drive oil pressure and temperature indicator circuits are connected to continuous power as contacts A1 and A2 close (Reference Figure 4-13).

The APU Electronic Controller is connected to APU controller continuous power as contacts B1 and B2 close. (Reference Figure 4-13). The APU Electronic Controller sequencer circuitry then initiates the APU automatic engine start sequence.

APU Electronic Controller's Start Sequence

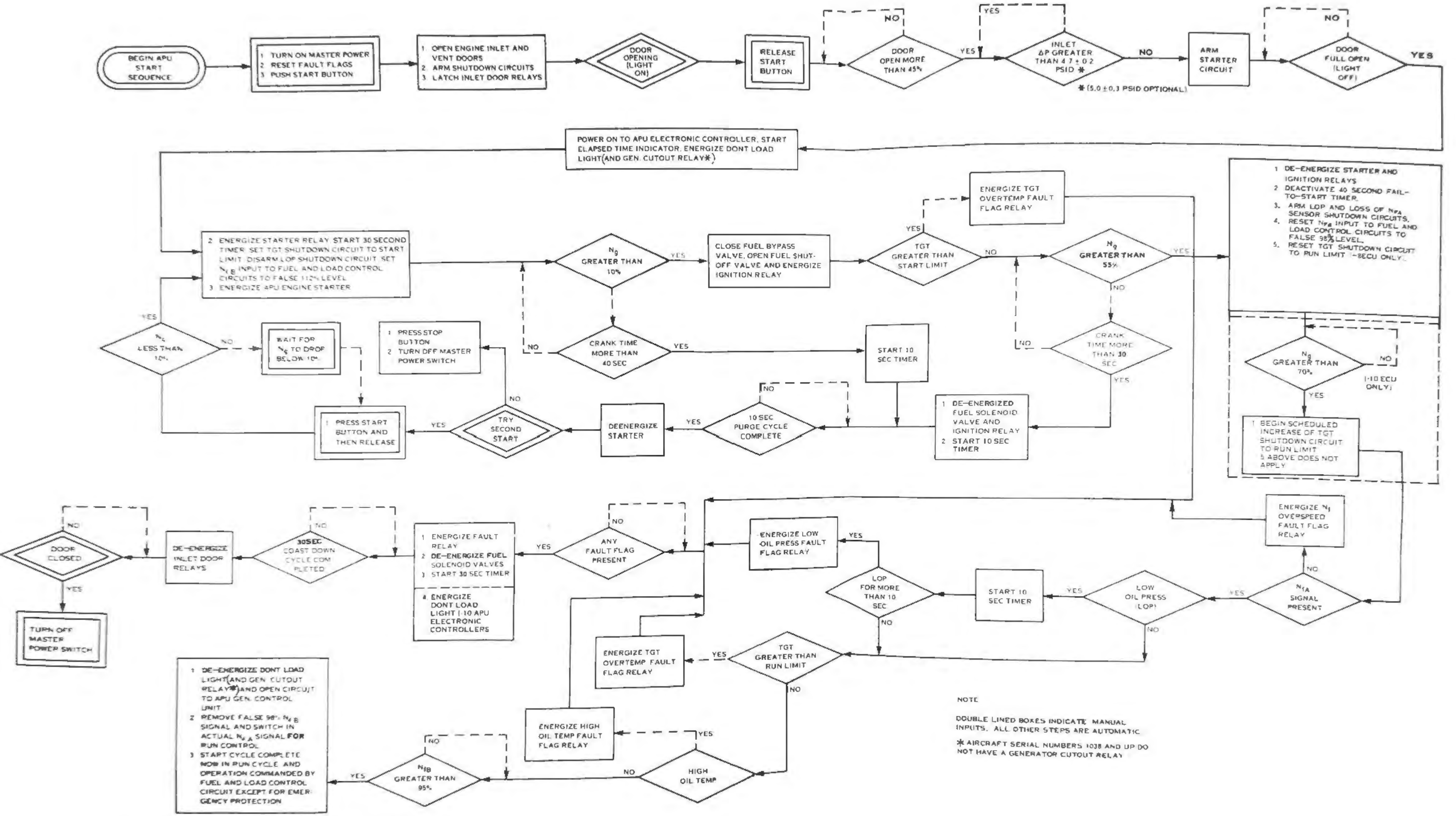
The APU engine start sequence (Figure 4-16) is initiated when the Power Control relay applies 28V dc to the APU Electronic Controller. The APU Electronic Controller causes the desired sequence of events to occur.

When the APU Electronic Controller senses that N_f is less than 95% and N_g is less than 10%, the APU Electronic Controller initiates the following events, simultaneously:

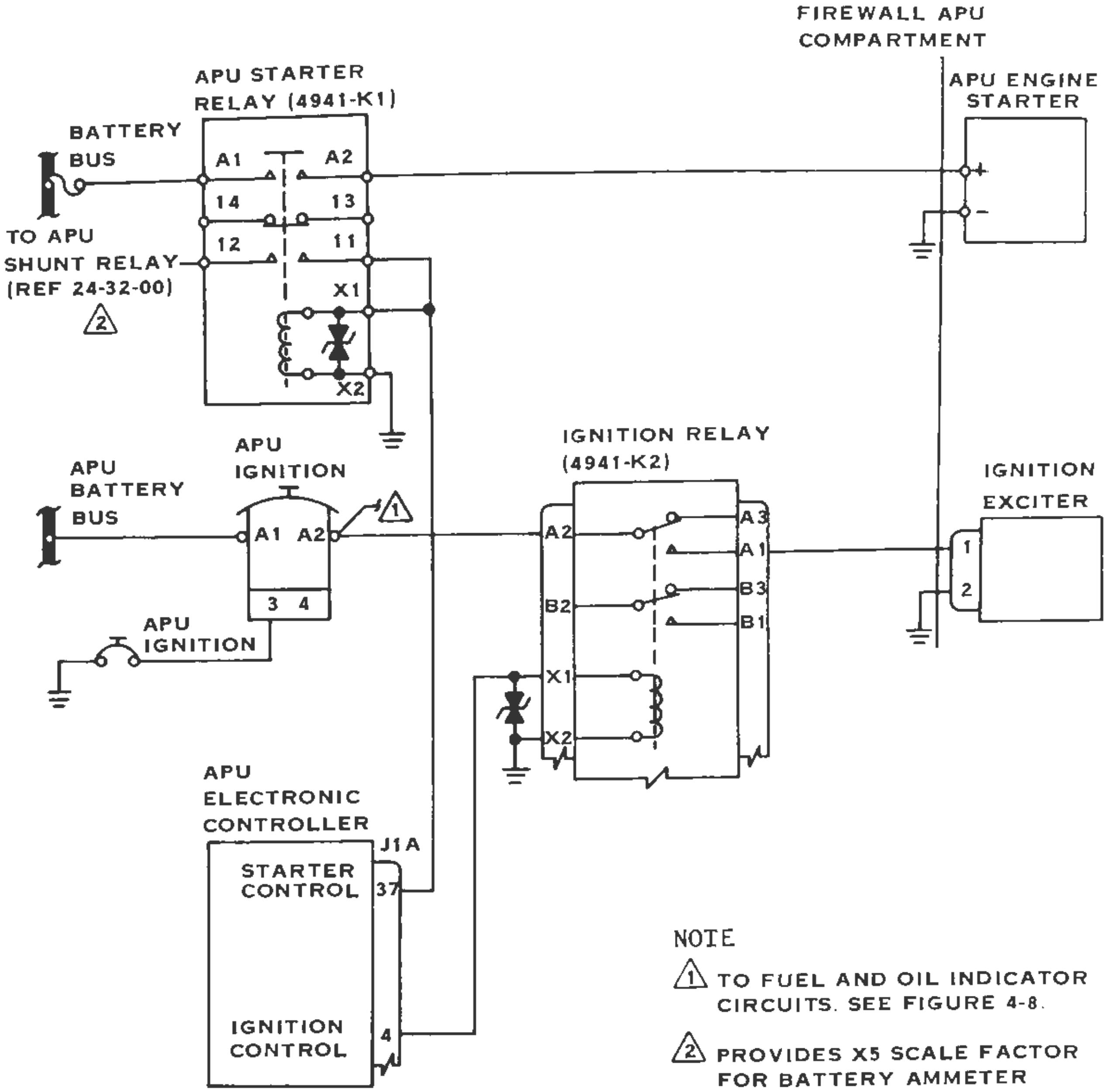
- The DONT LOAD indicator light is energized.

- A ground is provided to the generator control unit to prevent the APU ac generator from being tied into the aircraft electrical system.

- The Generator Cutout relay (aircraft through serial number 1037 only) is energized causing the continuous power circuit to transfer to the aircraft battery bus (Reference Figure 4-12A).



APU START CYCLE FUNCTIONAL FLOW CHART
FIGURE 4-16



NOTE

1. TO FUEL AND OIL INDICATOR CIRCUITS. SEE FIGURE 4-8.
2. PROVIDES X5 SCALE FACTOR FOR BATTERY AMMETER DURING APU CRANK

START AND IGNITION CONTROL FUNCTIONAL DIAGRAM
FIGURE 4-17

- The low oil pressure shutdown circuit in the APU Electronic Controller is disabled and the overtemperature shutdown circuit is set to the starting (lower) limit also, the loss of N_{fA} signal shutdown circuit is disabled.

- The sequencer switches a false 112% N_f speed reference signal into the speed governor system. This signal establishes a large N_f overspeed error which saturates the N_g speed controller to its low limit. N_g starting speed is therefore temporarily limited to minimum idle speed (Approximately 60%).

- A 30 second fail-to-start timing circuit is started.

- A sequencer relay (Starter Control relay) energizes, providing 28V dc to energize the aircraft APU Starter relay, and completing a path to arm the APU Electronic Controller's Ignition Control relay (Figure 4-17). The Starter relay applies battery bus power to the APU engine starter, and the engine begins to crank.

When the APU Electronic Controller senses that the gas generator speed has passed 10% N_g the APU Electronic Controller sequencer initiates the following:

- Opens the fuel shutoff valve by energizing its solenoid through one set of contacts of an internal (Fuel Solenoid Control) relay.

- Closes the fuel bypass valve by energizing its solenoid through another set of contacts of an internal (Fuel Solenoid Control) relay.

- Energizes the aircraft ignition relay through another internal (Ignition Control) relay.

- The APU starter (Reference Figure 4-17) continues to crank as the engine starts.

- Latches an internal (Power Fail Fuel Lockout) relay to arm the power interrupt/loss system shutdown circuit.

When the APU Electronic Controller senses that N_f speed is still less than 95% and the N_g speed has passed 55% N_g before the 30 second timer completes its cycle (successful start); the APU Electronic Controller sequencer initiates the following events, simultaneously:

- The 30 second fail-to-start timer is deactivated.

- The low oil pressure shutdown circuit is armed.

- The loss of N_{fA} signal shutdown circuit is armed.

- The overtemperature shutdown circuit is reset to the normal operating temperature limit and the temperature limiting N_g override circuit is enabled. (For P/N ED724438-8 APU Electronic Controllers only).

- The APU Engine Starter and Ignition relays are deenergized through separate sets of contacts of an internal (Starter Control) relay.

- The false free turbine speed reference is switched from the previous false 112% N_f to a false 98% N_f reference. This establishes a 2% low N_f speed error signal and causes the APU Electronic Controller to command a slow increase in gas generator speed, which also results in a slow increase in free turbine speed.

NOTE: If the fail-to-start timer completes the 30 second cycle before the gas generator speed passes 55%, or if the N_{fA} signal is not present when N_g reaches 55%, a precautionary shutdown is initiated. Simultaneously the fuel shutoff valve closes, the bypass valve opens, the ignition deenergizes, and a 10 second timer starts allowing engine cranking to continue for 10 seconds, purging the engine of any combustible gases that may remain from the "hung start". At the end of 10 seconds, the starter is deenergized. A restart can be immediately attempted if power is urgently needed. However, a waiting period of 30 seconds to allow the starter to cool is recommended. If the engine does not start after three attempts, the STOP button must be pressed (and a one hour starter cooling off period initiated) to close the engine inlet door and the vent ejector door, and the MASTER POWER switch on the APU CONTROL panel must be turned OFF to deenergize the Power Control relay. This removes power from the APU Electronic Controller and the APU elapsed time indicator and deenergizes the Inlet Door relays, to assure that the engine inlet door will be closed. Should a fail-to-start shutdown occur, this sequence must be followed, to assure that the engine inlet door will be closed.

For P/N ED724438-10 APU Electronic Controllers when the Ng speed signal passes 70%, the TGT shutdown set point begins to increase on a linear schedule such that the normal operating temperature limit is effective for an Ng speed greater than or equal to 95% RPM.

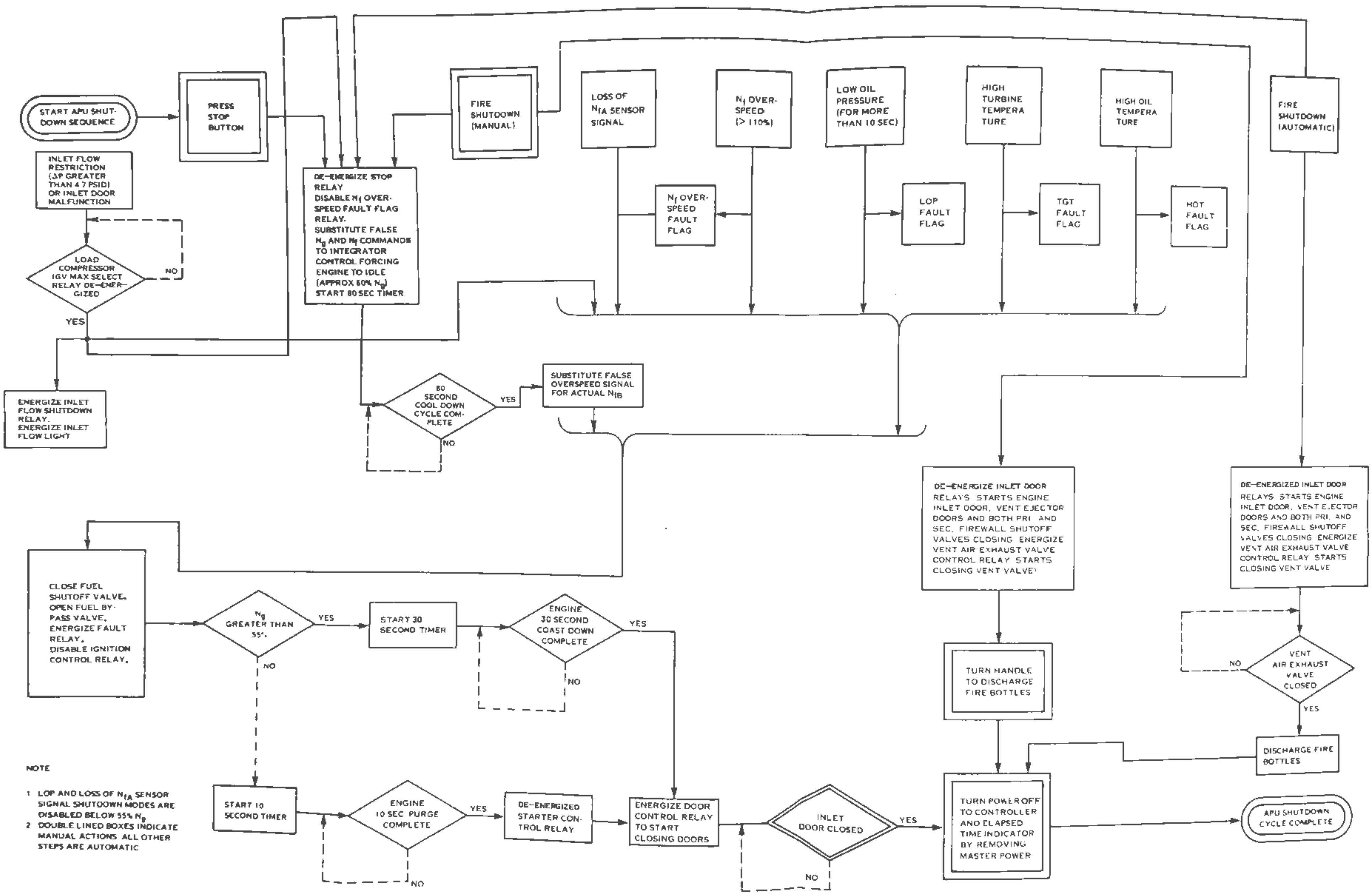
When the APU Electronic Controller senses that N_g has passed 55% and N_f has passed 95%, the APU Electronic Controller sequencer initiates the following events, simultaneously:

- The false 98% N_f reference is replaced with the actual N_{fA} speed signal which causes the APU Electronic Controller's N_g speed control circuit to regulate N_g to whatever speed necessary to hold N_f at 100 percent (33,000 rpm).

- The electrical ground to the aircraft generator control unit is removed and the APU ac generator is switched on the line.

- The DONT LOAD light goes OFF and (for aircraft through serial number 1037 only) the Generator Cutout relay is deenergized, which in turn energizes the T/R Power Control relay to transfer continuous control power from the aircraft battery bus to T/R power (Reference Figure 4-12A).

NOTE: Any later N_f speed transient below 95% will not completely reverse the above functions, but if N_f falls below 90% or increases above 105%, the signal to the aircraft APU generator control unit is grounded through the Generator Field Trip Time Delay relay to trip the APU ac generator off the line (Reference Figure 4-21). Simultaneously, the DONT LOAD indicator light (and the Generator Cutout relay in early aircraft) is again energized, through the action of the Generator Field Trip Time Delay relay upon command from the internal (Generator Load Control) relay in the APU Electronic Controller. This completes the APU engine start sequence, and the APU is now operating under automatic control by the APU Electronic Controller modulating circuits.



APU STOP CYCLE FUNCTIONAL FLOW CHART
FIGURE 4-18

MANUAL SHUTDOWN SEQUENCE

The APU shutdown sequence may be manually initiated from either the APU CONTROL panel or the external APU control panel. A normal shutdown is initiated by operation of the momentary STOP button, (a manual fire shutdown may be initiated by operation of a FIRE PULL handle). The shutdown sequence may also be automatically initiated by the Automatic Fire Shutdown relay or by the APU Electronic Controller if one of its protection circuits is activated.

When a normal shutdown is initiated by the STOP button, the APU ac generator is tripped off the line and the Stop relay deenergizes. This applies a stop command to the APU Electronic Controller and disconnects the N_f fault flag. The APU Electronic Controller sequencer immediately commands energization of the DONT LOAD light, commands the Free Turbine Speed Controller to the idle fuel flow position and initiates a timed shutdown sequence which keeps the APU engine operating for 80 seconds to allow cooling of the turbine section, then de-energizes the fuel solenoids and initiates another timed sequence which maintains the APU inlet door open for 30 seconds to allow engine coastdown. After the APU engine inlet door is closed, placing the MASTER POWER switch to the OFF position completes the shutdown sequence by removing power from the APU Electronic Controller, the elapsed time indicator, and the APU control circuits.

Normal Stop Sequence (Reference Figure 4-9)

Stop Relay Operation

When the STOP button is pushed (Reference Figure 4-9), the latch for the Stop relay is removed and it deenergizes causing the following events to occur:

- N_f OVERSPEED fault flag is disarmed by opening of contacts C1 and C2. This prevents the subsequent internal false N_f overspeed command from tripping the fault flag.
- A stop command is applied to the APU Electronic Controller by closing of contacts B2 and B3 initiating the normal stop sequence.

APU Electronic Controller Normal Stop Sequence

The APU engine normal stop sequence is initiated when the Stop relay is deenergized, completing a path to ground and actuating an internal transistor switch. This results in generating of a false command to drive the free turbine speed controller to idle fuel flow and also starts an 80 second timer for the idle cool down period. Completion of the 80 second time cycle shunts the actual N_{fB} signal and switches in a false 112% N_f overspeed signal in the APU Electronic Controller sequencer (thereby checking the primary overspeed shutdown circuit on every manual shutdown). A functional flow chart of the stop cycle is contained in Figure 4-18.

When the APU Electronic Controller senses the stop command, the APU Electronic Controller causes the desired sequence of events to occur:

- False less than 95% N_{fB} and less than 55% Ng signals are generated to command an intergrator to drive the Free Turbine Speed Controller to the idle fuel flow position.
- The 80 second timer is started.
- The internal Generator Load Control relay is denergized resulting in the following:
  - • Through the 6 second lag in the generator field, trip time delay.
  - • The DONT LOAD indicator light illuminates and (for aircraft through 1037 only) the Generator Cutout relay is energized, causing transfer of continuous power from T/R power to the aircraft battery bus.
  - • A ground is provided to the generator control unit, causing the APU aircraft generator to be taken off-the-line (this is a backup to the STOP button shutoff for a normal stop and the primary shutoff for protective shutdowns). As this occurs, the transfer of continuous power completes, and there is no interruption in power to the APU Electronic Controller and APU control circuits.
  - After the 80 second timer runs out a false N_f overspeed is switched into the N_{fB} overspeed comparator causing the N_f overspeed shutdown circuit to switch on simultaneously tripping the internal (Fault Shutdown Control) relay.

When the internal Fault Shutdown Control relay is energized and latched it causes the following to occur, simultaneously:

- A 30 second timing circuit is started, to delay deenergizing of the APU Inlet Door relays while the APU engine and free turbine coast down from high speed.
- The fuel shutoff valve is closed by deenergizing its solenoid through one set of contacts of this internal (Fuel Solenoids Control) relay.
- The fuel bypass valve is opened by denergizing its solenoid through one set of contacts of this internal (Fuel Solenoids Control) relay.
- The internal Ignition Control relay is disabled.

When the 30 second timer in the APU Electronic Controller "times out", the APU Electronic Controller energizes an internal relay which removes the latching ground from the APU engine Inlet Door relay 1. This simultaneously deenergizes both Inlet Door relays.

Inlet Door Relays Deenergization

When the APU Inlet Door relay 1 is deenergized, the following events occur:

- The open command to the secondary firewall shutoff valve is removed by contacts A1 and A2. (This valve always remains in the open position unless closed by a fire shutdown).

- The BLEED AIR S/O valve switchlight circuit is disarmed by contacts B1 and B2 (Aircraft 1002 through 1090 only).

- Contacts D2 and D3 close, applying 28V dc to the close coil of the engine inlet door actuator through contacts of the Power Control relay and the not-closed contacts of the limit switch. The APU engine inlet door then begins to close. Contacts F2 and F3 close, applying continuous power through the not-closed limit switch contacts in the vent ejector door actuator to the indicator lights control box (Reference Figure 4-15) and the DOORS IN TRANSIT indicator light illuminates.

When the APU Inlet Door relay 2 is deenergized, the following events occur:

- Contacts E2 and E3 close, applying power to the close coil of the vent ejector door actuator (Reference Figure 4-15) and the vent ejector doors being to close.

- Master power is removed from the APU Engine Inlet Door relays by contacts C1 and C2 opening. (The relays were previously deenergized by the APU Electronic Controller which removed the relay ground (Reference Figure 4-13).

- As contacts B2 and B3 close, continuous power is applied to the DOORS IN TRANSIT indicator circuit through contacts E1 and E2 of the still energized Power Control relay and the not-closed contacts of the APU engine inlet door actuator close limit switch.

NOTE: Both the vent ejector doors and APU engine inlet door must go full closed before the DOORS IN TRANSIT indicator light goes off (Reference Figure 4-15).

- As contacts F1 and F2 open, continuous power is transferred from T/R power to aircraft battery bus.

NOTE: This applies only to aircraft S/N 1038 and up (Reference Figure 4-12B). For earlier aircraft, opening of contacts F1 and F2 has no effect since continuous power transfer occurred when the Generator Cutout relay was energized (Reference Figure 4-12A).

- Contacts D2 and D3 close (paralleling the already closed Generator Cutout relay contacts B1 and B2), a circuit is completed to assure that when the next start cycle is initiated, power will be provided to the reset coil of the T/R Power Control relay, if the relay was not reset by a normal shutdown logic.

NOTE: This applies only to aircraft S/N 1002 through 1037.

When the APU engine inlet door reaches the full closed position (Reference Figure 4-15) one pole of the closed limit switch removes power from the close coil of the APU engine inlet door actuator. (Similarly, a limit switch in the vent ejector door actuator removes power from its close coil when the vent ejector doors reach full closed). Another pole of the inlet door closed limit switch removes continuous power from the following:

- DOORS IN TRANSIT indicator circuit which goes out when both the APU engine inlet door and vent ejector doors are full closed.

- Master Power Reset relay in which contacts A1 and A2 open, removing one source of continuous power from the hold coil of the MASTER POWER switch. The hold coil is still powered through the POWER ON switchlight on the external APU control panel, so the MASTER POWER switch will remain ON. (Reference Figures 4-12).

- Power Control relay coil. This is a parallel source so the relay remains energized, latched by its C1 and C2 contacts to continuous power (Reference Figure 4-13). However, energizing the Start relay will remove this latch and deenergize the Power Control relay until the door reopens.

When the MASTER POWER switch is selected to OFF, or the POWER ON switchlight on the external APU control panel is pressed (Reference Figure 4-12), Contacts 4 and 6 of the MASTER POWER switch open, deenergizing the APU BAT PWR RCCB. The coil of the T/R Power Control relay deenergizes and removes T/R power from the APU battery bus, and the Power Control relay deenergizes and removes power from the APU Electronic Controller and APU elapsed time indicator and the control circuits. With this, the normal manual shutdown sequence is completed.

NOTE: For a manual fire shutdown the sequence of events is similar to that for a normal stop except that the APU Engine Inlet Door relays are denergized simultaneously with the Stop relay (no cool down or coastdown periods) and the secondary firewall shutoff valve is closed.

Because of time periods involved, the shutdown occurs from fuel starvation and opening of the inlet door malfunction switch while the 80 second idle cool down timer is still running.

AUTOMATIC SHUTDOWN CIRCUITS

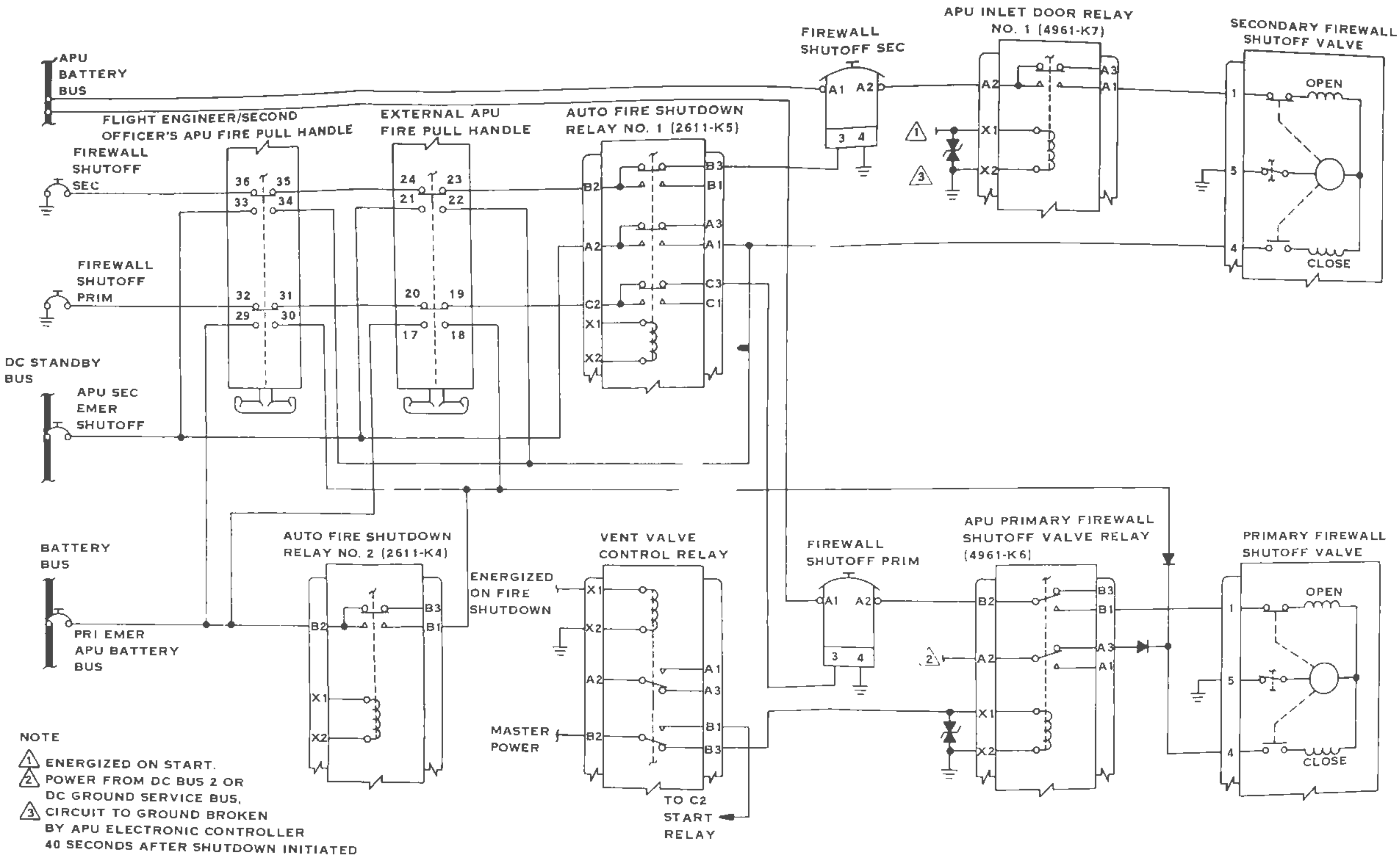
In addition to the manual shutdown provisions (STOP buttons or either FIRE PULL handle), the APU Control System may initiate an automatic shutdown from any one of ten events to provide engine protection against foreseeable potentially harmful conditions. These ten events are listed as follows:

Cause of Shutdown	Shutdown Indicator
• N_f Overspeed Protection Circuits • • Primary (110% N_{fB}) • • Backup 112% N_{fA}, 110% N_{fA} for -8 APU Electronic Controllers incorporating SB HS Code L1011 APU No. 24 and all -10 Controllers)	N_f Flag
• • Loss of N_{fB} sensor	DONT LOAD light comes on followed by an N_f flag as free turbine accelerates to an overspeed.
• Loss of N_{fA} Sensor Protection Circuit (0% N_{fA})	N_f Flag
• Low Oil Pressure (LOP) Protection Circuit (Open Switch)	LOP Flag
• High Oil Temperature (HOT) Protection Circuit (Closed Switch)	HOT Flag
• TGT Over Temp (HTT) Protection Circuit	TGT Flag
• Accidental APU Inlet Door Closure (Door More than 50% Closed)	No Flags. TGT and % N_g RPM Drop to Zero
• High APU compressor inlet pressure differential (ΔP switch opens)	No Flags. Inlet flow light on.
• Loss or Interruption of Electrical Power (Power Fail Fuel Lockout Circuit)	No Flags. TGT and %Ng RPM Drop to Zero.
• Loss of N_g Sensor (Controller Logic Sees N_g Less Than 10% Disables the Fuel Solenoids).	No Flags. TGT and % N_g RPM Drop to Zero.
• Autofire Shutdown Relay Circuit Energized	No Flags. Doors close and TGT and %Ng RPM Drop to Zero. Fire Horn Energized.

Engine Protection Shutdowns

Any one of the first five engine protection conditions listed above will command the APU Electronic Controller sequencer to trip the appropriate fault flag and initiate a shutdown sequence similar to that initiated for a normal manual stop.

For aircraft equipped with APU Electronic Controllers of earlier configurations (prior to P/N ED724438-10) it is possible for more than one flag to be tripped,



APU FIREWALL SHUTOFF VALVE CONTROL FUNCTIONAL DIAGRAM
FIGURE 4-19

since loss of the N_{fA} signal and LOP condition can occur while the engine is coasting down (55% N_g, comparator is latched). In this case, the first flag that appears is the real cause of the shutdown, and if the TGT or HOT flags appear the N_f OVERSPEED and/or LOP flag may be ignored. For ED724438-10 APU Electronic Controllers, such combinations of multiple fault flags are inhibited.

Since the OVERSPEED N_f fault flag is tripped by either N_f overspeed condition or loss of the N_{fA} sensor, the actual fault may be isolated by a restart attempt. If the N_{fA} sensor signal is not received by the APU Electronic Controller, a shutdown will occur immediately when N_g passes 55% during start.

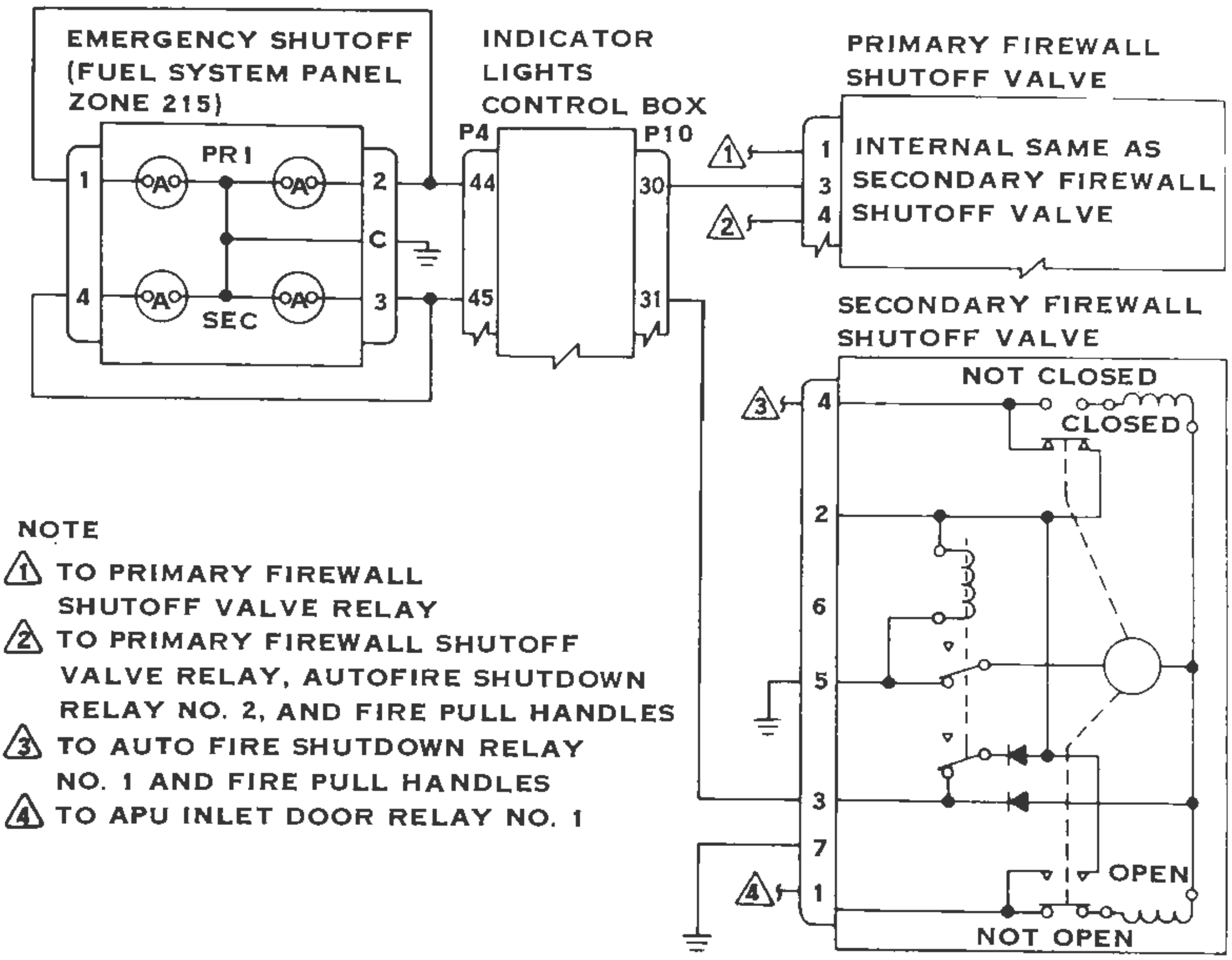
Accidental closure of the APU engine inlet door, caused by a malfunction in the control logic or in the door itself, generates an automatic APU shutdown command. A door malfunction switch in the engine inlet door actuator is normally closed whenever the door is open more than 50%, enabling normal APU operation. When the door closes below 50% the switch opens, resulting in the APU Electronic Controller immediately shutting down the APU by closing off fuel flow to the engine. An inlet pressure ΔP switch in series with the door malfunction switch will actuate and shutdown the APU if there is an inlet restriction (such as ice) in the Load Compressor inlet duct. These shutdown modes are de-energized when the IGV MAX select relay is energized. If the continuous power circuit should become deenergized, the APU Electronic Controller will lose its power input, and the fuel bypass valve is opened (solenoid deenergized) and the fuel shutoff valve is closed (solenoid deenergized). No power is available to close the engine inlet door, so it will remain open. (Unless the fault is due to an open electrical wire to the APU Electronic Controller's power inputs).

If the gas generator (N_g) tachometer signal to the APU Electronic Controller is interrupted or lost, internal logic will command an immediate shutdown by removing the energizing signal to the fuel solenoids (fuel bypass valve opens and the fuel shutoff valve closes). In this case, no fault flag will be energized, the 40 second timer will not be started, and the APU engine inlet door will remain open. A restart will then be inhibited because the N_g signal is necessary to energize the fuel solenoids.

Automatic Fire Shutdown (Figures 4-19 and 4-20)

When the aircraft is in flight and the AUTO FIRE SHUTDOWN switch on the APU control panel is in the ARMED position, the two Auto Fire Shutdown relays are armed to receive energizing voltage from the fire detection circuit. The Auto Fire Shutdown relays are armed at all times when the aircraft is on the ground. If the fire detector energizes the Auto Fire Shutdown relays, the following events occur. (Similar events occur for manual operation of a FIRE PULL handle except that the fire bottle discharge is not automatic and is independent of vent air exhaust valve status.)

- The APU engine inlet door begins to close (Reference Figure 4-13) as contacts E2 and E3 of Fire Shutdown relay 1 open to remove latching power from the APU Inlet Door relays. These relays then deenergize,



APU FIREWALL SHUTOFF VALVE INDICATOR FUNCTIONAL DIAGRAM
FIGURE 4-20

causing door closure and othor logic functions as outlined under the MANUAL SHUTDOWN SEQUENCE.

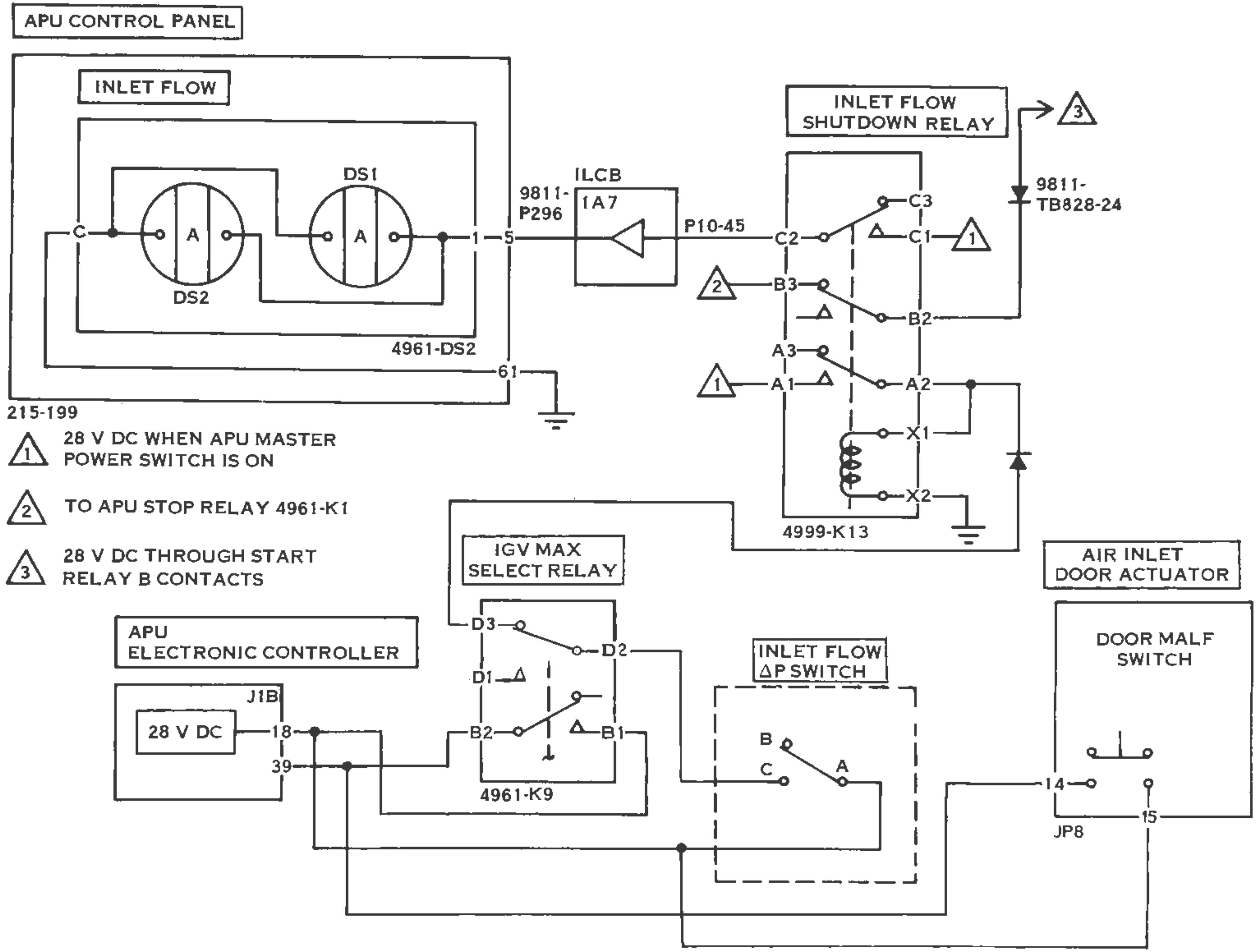
- The vent air exhaust valve begins to close (Reference Figure 4-14) as contacts E2 and E1 of Fire Shutdown relay 1 close, applying master power to the vent air exhaust valve control relay (the relay energizes, latches, and contacts A1 and A2 apply power to the close coil of the vent air exhaust valve). The vent air exhaust valve control relay is unlatched when the START switchlight is operated on the next APU start. Note that the vent air exhaust valve is normally open and only closes when a fire shutdown is initiated. When the vent air exhaust valve reaches full closed, the main APU Fire Extinguisher Bottle discharges.

- The APU Electronic Controller initiates a normal engine shutdown sequence as contacts F2 and F3 of Fire Shutdown relay 1 open, removing latching power from the Stop relay. (The Stop relay deenergizes, applying a stop command to the APU Electronic Controller, and the APU Electronic Controller initiates the same shutdown sequence as previously outlined under the Normal Stop Sequence).

- The primary and secondary firewall shutoff valves drive closed. Also, the open coils of both valves are inhibited by opening the RCCB's which provide power for the open coils. (Reference Figure 4-19 and 4-20.)

NOTE: The secondary firewall shutoff valve is only closed by a fire shutdown. The valve receives an open command during the next start cycle and remains open until another fire shutdown occurs.

The continuous power circuit remains energized after a fire shutdown and the MASTER POWER switch must be turned OFF to remove continuous power.



INLET FLOW PROTECTIVE SHUTDOWN FUNCTIONAL DIAGRAM
FIGURE 4-21

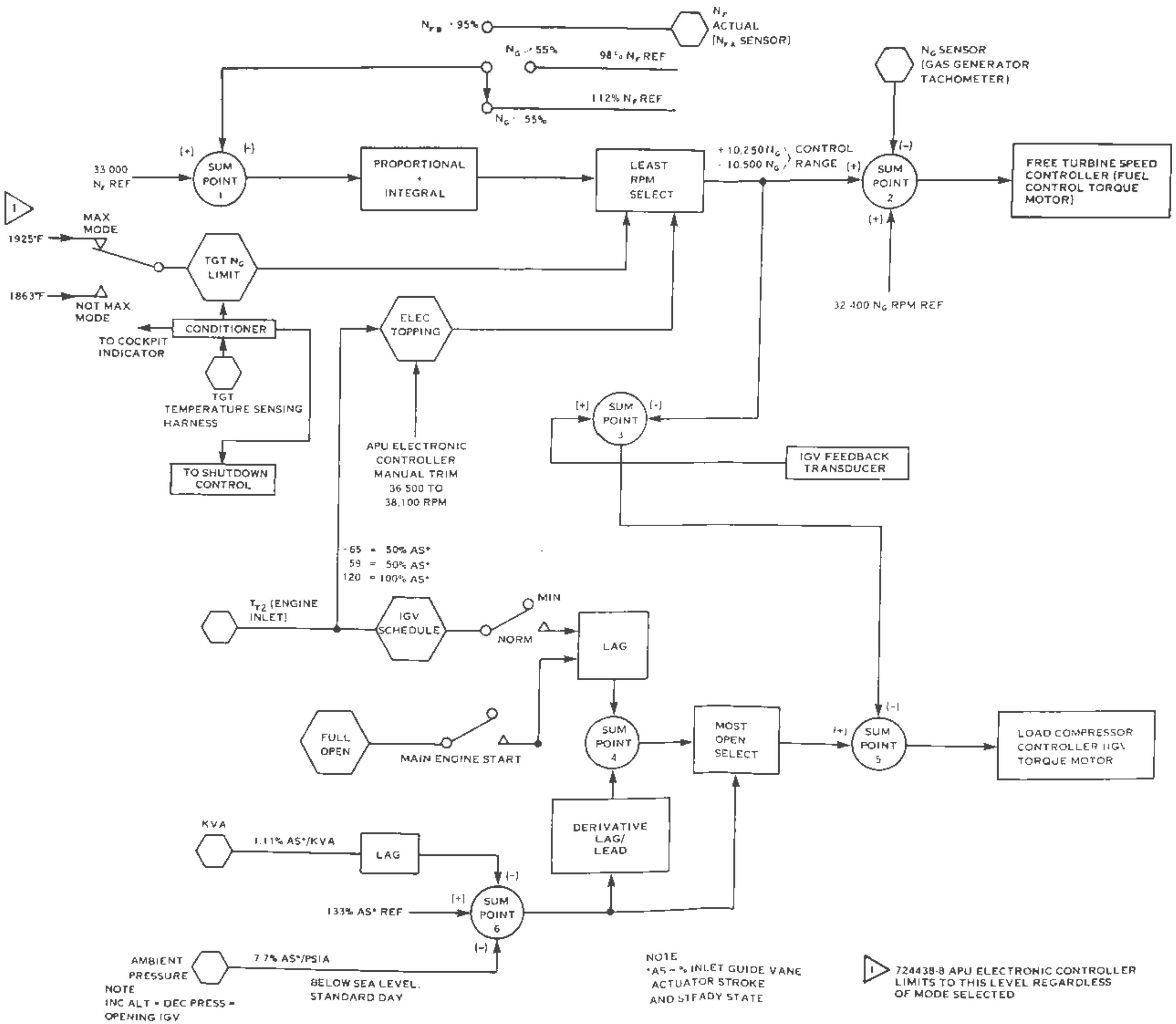
INLET FLOW Shutdown (Figure 4-21)

If the load compressor inlet flow is restricted (such as ice build-up or foreign object ingestion), it is desirable to shutdown the APU Engine to minimize the possibility of load compressor damage. A differential pressure (ΔP) switch, sens both ambient pressure and load compressor inlet pressure energizes the inlet flow shutdown relay causing a normal APU shutdown. It is desirable to disable this cir when MAX MODE operation is selected. This is done by placing the open (in MAX MODE) D2 and D3 contacts of the IGV Max Select relay in series with the ΔP switc to prevent actuation of the inlet flow shutdown relay.

If inlet pressure differential exceeds the ΔP switch trip point, and MIN or NORM M operating conditions apply, the following events occur:

- ΔP switch B and C contacts closed, energizing Inlet Flow Shutdown relay
  - Inlet Flow Shutdown relay A2 and A1 contacts close, latching the rela application of MASTER POWER.
  - Inlet Flow Shutdown relay B2 and B3 contacts open, deenergizing the APU stop relay causing a normal shutdown sequence.
  - Inlet Flow Shutdown relay C2 and C1 contacts close, energizing INLET FLOW indicator light on the APU CONTROL PANEL.

NOTE: MASTER POWER switch must be cycled off and back on to unlatch the Inlet Flow Shutdown relay and permit another APU start attempt.



APU ELECTRONIC CONTROLLER TRANSIENT AND STEADY STATE FUNCTIONAL DIAGRAM
FIGURE 4-22

MODULATING CONTROLS

The speed control system (Figure 4-22) consists of free turbine speed control and load topping control. The basic components in this system are the APU Electronic Controller, free turbine (N_f) speed sensors, a gas generator (N_g) tachometer, a free turbine speed controller (fuel control torque motor) an IGV load compressor controller (IGV torque motor), an IGV Feedback Transducer and a Tt2 sensor.

Free Turbine Speed Control

To maintain the accurate steady state speed requirements of the free turbine, a constant speed electronic governor is used. Actual free turbine speed is sensed and compared to a fixed reference N_f value within the APU Electronic Controller, which then calculates a gas generator speed reference change (delta N_{gR}) based on the N_f error. The integral control portion continues to vary delta N_{gR} until the error between the reference N_f and the actual N_f (free turbine speed) is zero.

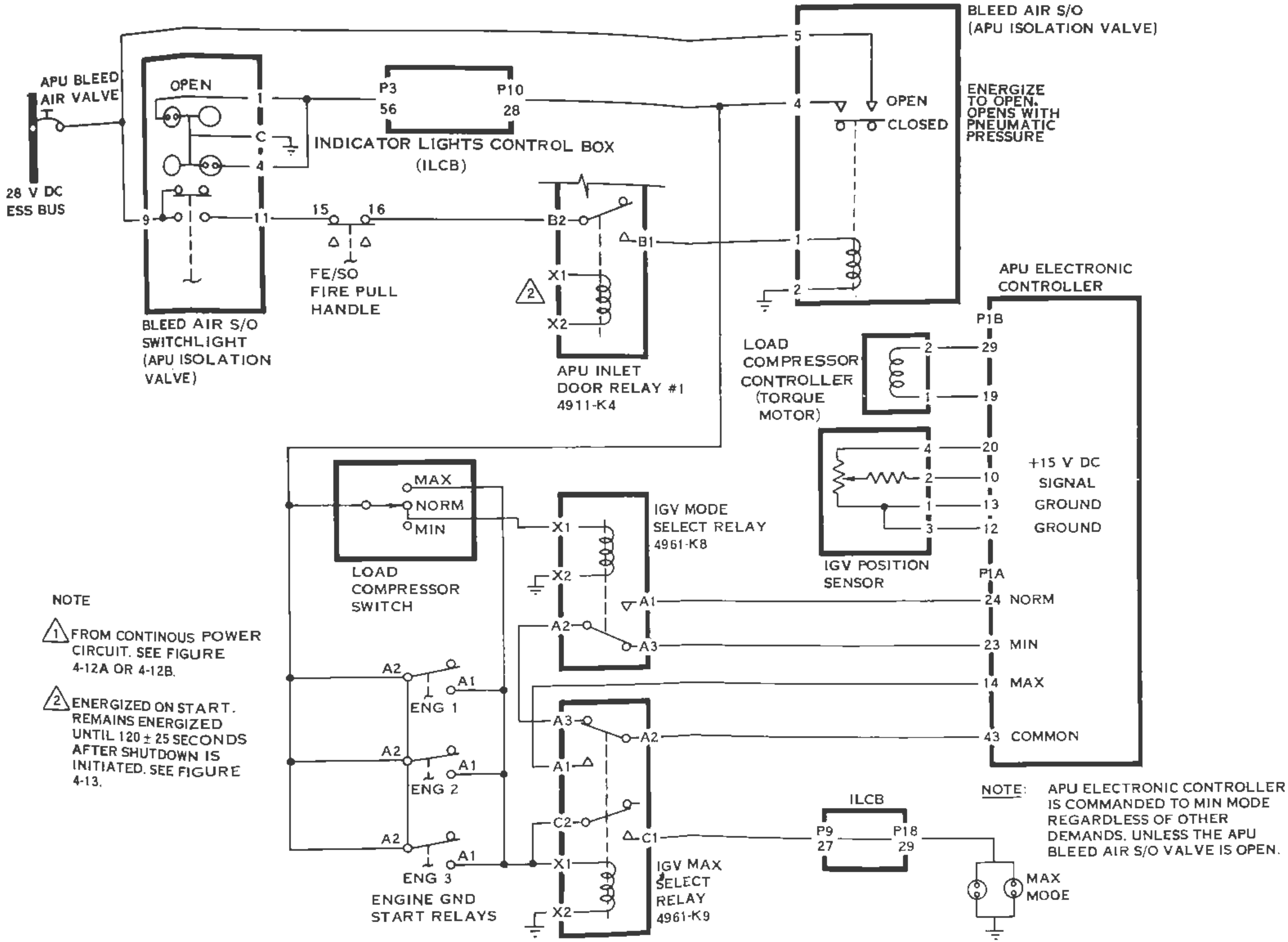
The gas generator speed reference change (delta N_{gR}) is summed with a constant gas generator speed reference (N_g set ref). The summed signal is compared to the actual N_g (gas generator speed) within the APU Electronic Controller, which then drives the free turbine speed controller (fuel control torque motor) to vary fuel flow and reduce the resultant error to zero. Actual gas generator speed change is proportional to the change in fuel flow. This change in speed and fuel flow produces the required change in gas generator speed to maintain the free turbine speed at 33,000 rpm (100%) under changing load conditions.

During engine startup, the free turbine speed (N_f) signal is switched as described under Start Sequence. This assures an APU start for any pneumatic load condition and provides good cold engine start thermal characteristics. The gas generator is slowly accelerated (well below maximum acceleration) to the power level that drives the free turbine speed to 95% (for any inlet guide vane position of the load compressor) before normal feedback control is initiated. Thus, the initial turbine temperatures are reduced during startup due to the slow acceleration.

Protection from flameout ("rich blowout" or "lean die out"), compressor surge and high turbine temperature during acceleration, are provided by the maximum fuel flow/compressor discharge pressure ratio (W_f/P_3) and by minimum fuel flow limits incorporated in the APU engine fuel control unit.

Load Topping Control

If engine power conditions exceeding maximum rating (data plate trim speed) are commanded by the N_f speed control, the load topping system is initiated. The gas generator topping (N_g limit) speed, which is directly related to engine power, is determined by an adjustable limiting speed schedule. If free turbine load



IGV CONTROL FUNCTIONAL DIAGRAM
FIGURE 4-23

exceeds the power available at this limiting speed, the load compressor inlet guide vanes are biased closed to reduce compressor supply (giving priority to the electrical load). This maintains constant free turbine speed even though the gas generator speed limits at the topping setting.

If the gas generator speed reference signal (delta N_{gR}) out of the proportional-plus-integral controller section is greater than the limiting speed, the actual reference signal (N_g ref) into the gas generator summing junction is the limiting value. The difference between the limiting value and the output of the APU Electronic Controller (delta N_g top) is used to bias the reference signal to the load compressor inlet guide vane actuator. The load compressor inlet guide vanes are modulated by the APU Electronic Controller until the free turbine speed error is zero.

At very low inlet temperatures, choking of the compressor inlet is the limiting power criterion. At intermediate inlet temperatures, maximum gas generator speed conditions are the limiting criteria. As inlet temperature increases further, maximum turbine temperature becomes the limiting condition. The limiting gas generator speed schedules are incorporated within the APU Electronic Controller and are varied with inlet temperature or TGT, as applicable, to meet these criteria. At inlet temperatures from 103°F to near 0°F, the limiting speed is constant and is set at the APU engine data plate value (gas generator speed for rated power on a 103°F day during installation) by a trim adjustment on APU Electronic Controller. At inlet temperatures above 103°F and below 0°F, the limit schedule is reduced. Provisions are incorporated into the limiting schedule to manually trim the schedule to account for engine-to-engine variation and deterioration in performance during engine life.

All APU Electronic Controllers (P/N ED724438-8 and subsequent) include an additional load topping control function which schedules an N_g limiting reduction as a function of TGT rise above a preset level (less than the engine protection shutdown setpoint) to reduce turbine loads during heavy load operating conditions. This limiting schedule is not directly influenced by the installation trim adjustment which biases the normal N_g limiting schedule. For APU Electronic Controllers, P/N ED724438-8, this schedule operates in all load compressor modes at a TGT greater than 1925°F. For P/N ED724438-10, TGT limiting operates greater than 1925°F in MAX mode and greater than 1863°F in MIN or NORM mode.

Load Control (Figure 4-23

The compressor load switch on the APU CONTROL panel is used to select one of three modes of operation: minimum, normal or maximum.

Minimum load control (MIN MODE) is accomplished by a manual override signal or by an automatic signal (bleed air S/O valve not closed) during APU start. Either signal commands the APU Electronic Controller to MIN MODE operation which overcomes the normal control and forces the IGV to the closed stop position, which reduces the compressor flow, and therefore the load, to minimum.

Normal load control (NORM MODE) is accomplished by scheduling the load compressor inlet guide vanes (IGV) as a function of inlet temperature to provide

a nominally constant mass airflow from the load compressor at sea level conditions. As temperature decreases, the IGV must be partially closed to maintain adequate airflow capacity. The IGV position to maintain adequate airflow capacity is based on normal system resistance and inlet temperature. The scheduled IGV position is determined as that producing the required airflow compatible with engine limits and load demands.

The maximum load control (MAX MODE) is commanded by a momentary manual or automatic signal. Automatic control occurs whenever an aircraft engine starter is actuated, by a signal from the engine ground start relay (through the APU bleed air shutoff valve circuitry) which drives the load compressor inlet guide vanes to the maximum open stop position to ensure maximum pressure supply to the main engine starter. When the engine ground start relay is denergized, the inlet guide vanes return to the mode of control selected by the APU control panel switch position. This function requires that the bleed air shutoff valve be open. Holding the compressor load switch in the MAX MODE position also commands maximum load control.

NOTE: The MAX MODE position is intended for intermittent use such as the last (or final) phase of main engine ground thrust reverser checkout, or for APU inlet guide vane trouble shooting.

In NORM MODE, the desired IGV signal is passed through a lag circuit to limit the rate at which any normal flow change is imposed, preventing any adverse transient effects.

The IGV load compressor controller (torque motor) operates an open-centered, double-acting, pneumatic flapper valve. This valve drives a half-area-type actuator which powers the IGVs through a linkage and gear arrangement. The position of the IGVs is transduced by a voltage divider type feedback transducer (potentiometer) on the actuator, and fed to the summing amplifier in the APU Electronic Controller. This signal is summed with a reference signal and the resulting error drives the IGV load compressor controller until the desired IGV position is obtained. A nonlinear position relationship between the IGV actuator and the IGV angle is incorporated to cancel the inherent nonlinear relationship between horsepower and IGV angle.

Transient Control

A free turbine engine responds to power changes as follows: As fuel flow is changed, the corresponding temperature change immediately causes a partial change in power output. The gas generator then accelerates or decelerates to a new steady state speed. The change in speed causes a corresponding change in engine mass air flow rate which accounts for the remainder of the total power change. The total response of the free turbine to rapid power changes is limited by the acceleration limits of the gas generator. The transient control system is used to aid the speed system (when required) to maintain minimum transient

speed errors when large electrical step loads are applied. Because the acceleration rate is a direct function of inlet pressure, the engine response is fast at sea level and little aid is required from the transient control to maintain speed variations within demand requirements. However, as the altitude increases (and the acceleration rate decreases), more aid from the transient control system is required to maintain acceptable transient speed response.

The transient control system functions by rapidly changing the compressor load by turning the inlet guide vanes in a direction opposite to the electrical load change, which reduces the effective load change imposed on the engine.

A P ambient transducer(pressure sensor) on the APU Electronic Controller is used to apply more compressor load (open the IGV's) as a function of increasing altitude. The electrical load sensor (current transformer) changes the amount of compressor load in response to electrical load changes. A 0.47 to 0.71 second lag filter is provided in the electrical load sensing circuit of the APU Electronic Controller to attenuate any electrical load excursions such as can be expected when paralleled to other aircraft generators.

FAIL-SAFE PROVISIONS

The complexity of the APU and electronic control system requires as many attendant fail-safe provisions as is feasible. In addition to the automatic shutdown protection features previously described, the following are employed:

<u>Fuel Shutoff Valve</u>

A normally closed solenoid valve in which loss of power or coil failure shuts off fuel flow which stops the APU.

<u>Fuel Bypass Valve</u>

A normally open solenoid valve in which loss of power or coil failure bypasses fuel around the fuel pump, causing the pressure to drop at the input of the minimum pressure valve. The minimum pressure valve closes and shuts off fuel flow to stop the APU.

<u>Free Turbine Speed Controller</u>

Loss of power or a complete electrical (torque motor) failure causes the free turbine speed controller to return to the minimum fuel flow setting of the APU engine fuel control unit.

<u>IGV Load Compressor Controller</u>

Loss of power or a complete electrical (torque motor) failure, causes the load compressor controller to move to a position which drives the inlet guide vanes toward full open thereby loading the engine.

<u>Gas Generator Tachometer</u>

Failure resulting in complete loss of N_g speed signal will cause the APU Electronic Controller to immediately remove fuel if the APU is operating, or prevent fuel initiation during a start attempt.

<u>Free Turbine Speed Sensors</u>

N_{fA} (Bottom) Sensor

Failure resulting in complete loss of this N_f speed signal will cause the APU Electronic Controller to bypass the internal N_f overspeed circuitry and actuate the the N_f overspeed shutdown function tripping the fault flag on the APU CONTROL panel as the APU engine is shutdown.

N_{fB} (Top Sensor)

Failure resulting in loss of the N_f speed signal does not disable the overspeed protection shutdown feature since a redundant "fail-safe" circuit which senses N_{fA} (bottom sensor) will independently actuate the N_f overspeed shutdown circuit to trigger the automatic shutdown. However, loss of N_{fB} sensing will result in the APU Electronic Controller keeping the DON'T LOAD light (and the Generator Cutout relay, if applicable) energized and command the generator control unit to keep the APU generator off the line. Further, with the N_{fB} sensor inoperative, the Ng speed will slowly increase until the secondary N_f overspeed protection shutdown circuit is actuated since the APU Electronic Controller sequencer holds the false 98% N_f reference as an input to the free turbine speed control loop.

Bleed Air Shutoff Valve (APU Isolation Valve)

Failure of the Bleed Air SOV to open will result in the inlet guide vanes being positioned to the MIN mode position.

Low Oil Pressure Switch

Failure resulting in LOP switch not closing, opening or being disconnected will command a LOP shutdown approximately 10 seconds after failure occurs or 10 seconds after Ng passes 55% on APU start up if LOP switch system or wiring failure is already present.

ΔP Switch

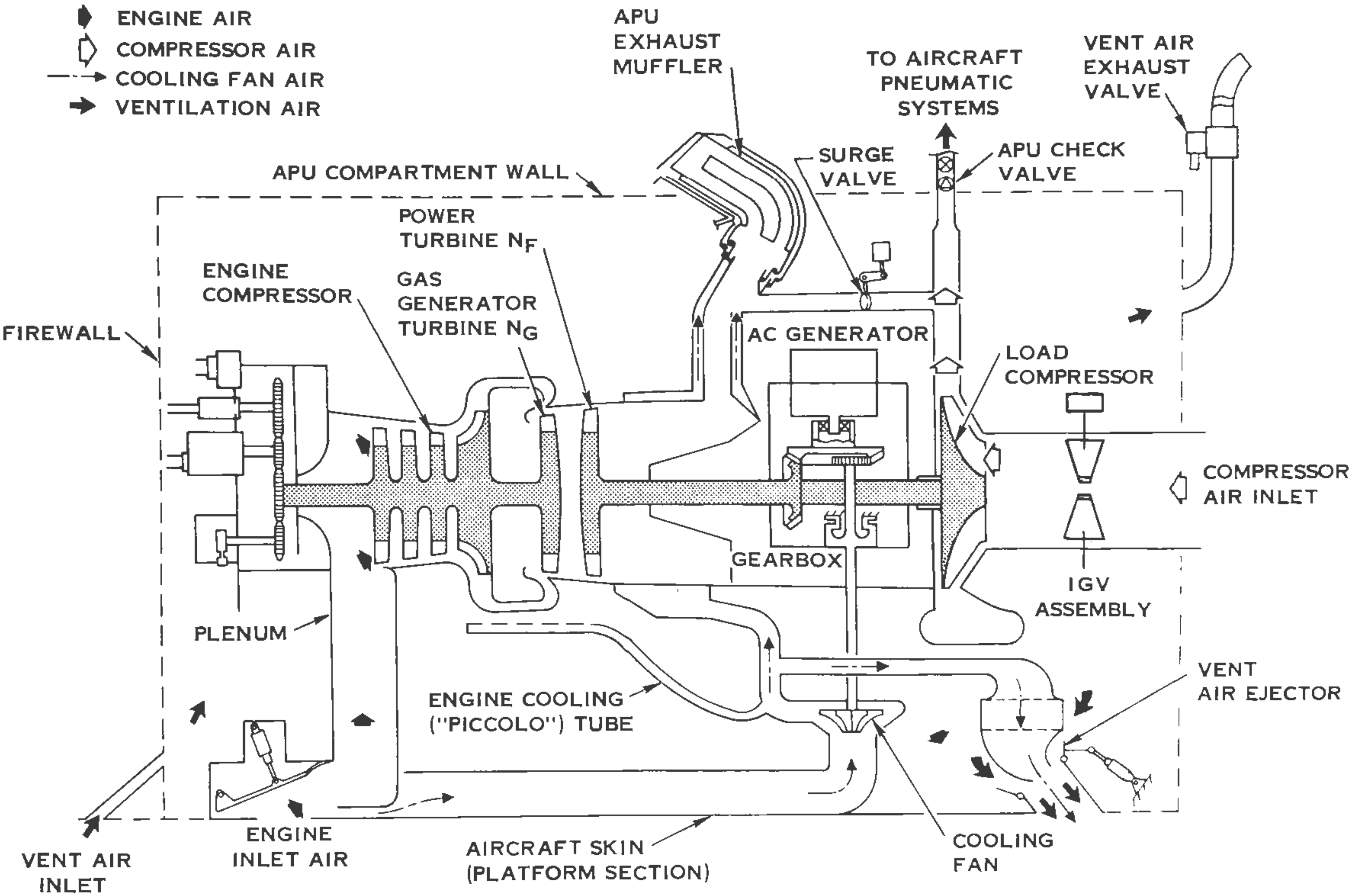
Failure resulting in closure of the normally open ΔP switch contacts will result in normal shutdown and/or prevent an APU start. Flight station APU control panel indicator INLET FLOW light will be on.

APU COMPARTMENT INTERFACES

APU COMPARTMENT INTERFACES

GENERAL

This section describes the main engine air flow in addition to the APU aircraft compartment air flow during normal operation and during abnormal or fire shutdown mode.



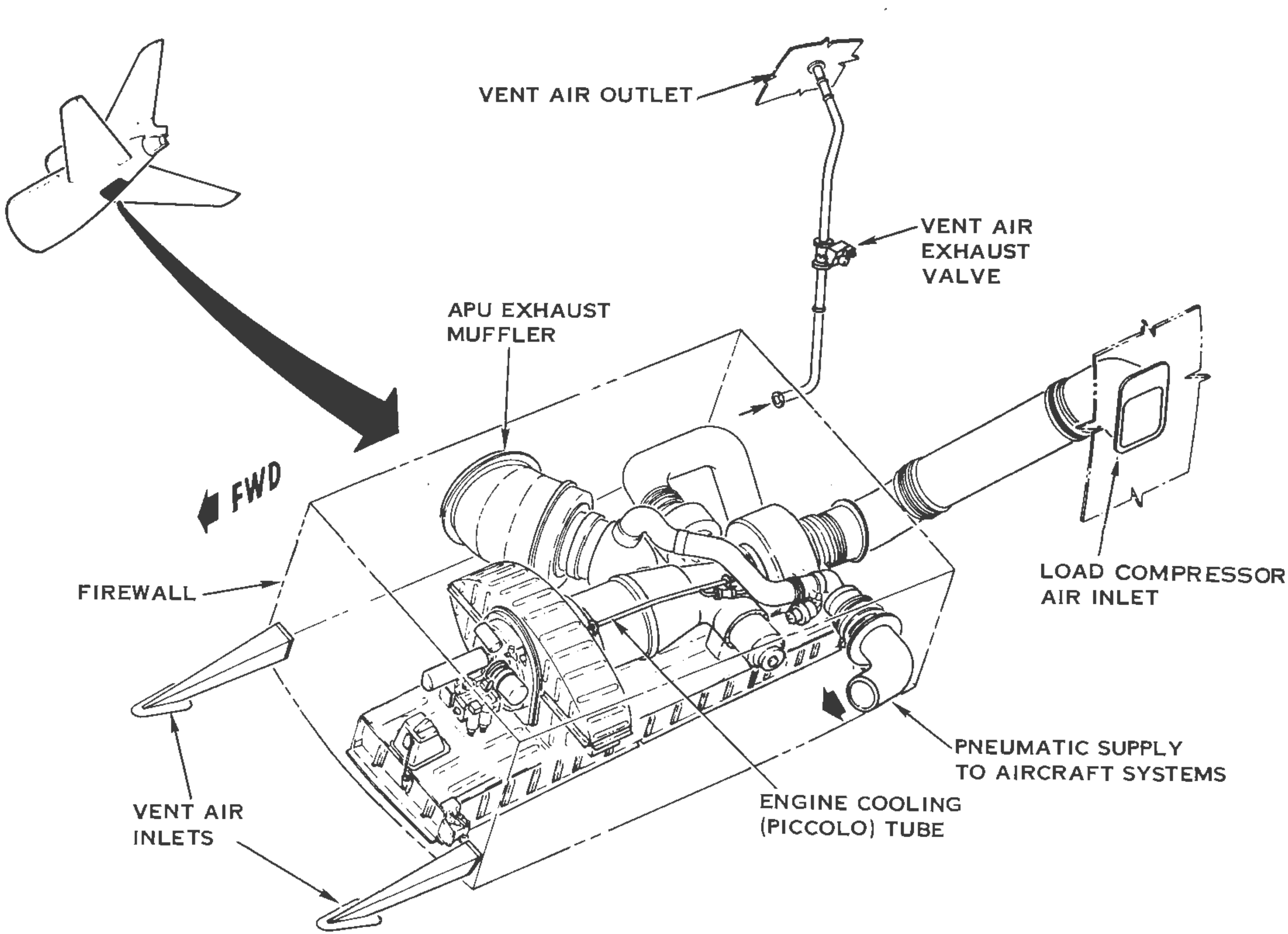
APU COMPARTMENT VENT SYSTEM SCHEMATIC
FIGURE 5-1

APU Compartment Air Flow

The APU compartment (Figure 5-1 and Figure 5-2) receives air from two flush scoops in the bottom of the fuselage just forward of the compartment. The scoops connect to openings in the compartment forward bulkhead at the lower outboard corners.

Air also enters the compartment through the engine air inlet door. Most of this air is drawn into the engine but a portion flows through the platform plenum to the cooling fan. The cooling fan pumps air to the engine cooling (piccolo) tube which directs cooling air across the top of the engine. Another portion of this air pumped by the cooling fan flows along the exhaust muffler walls and leaves with the engine exhaust air. A third portion is sent through the oil-to-air heat exchanger and out the vent air ejector.

Flow through the vent ejector induces compartment exhaust air flow. Additional ventilation air leaves thru the vent air exhaust valve.



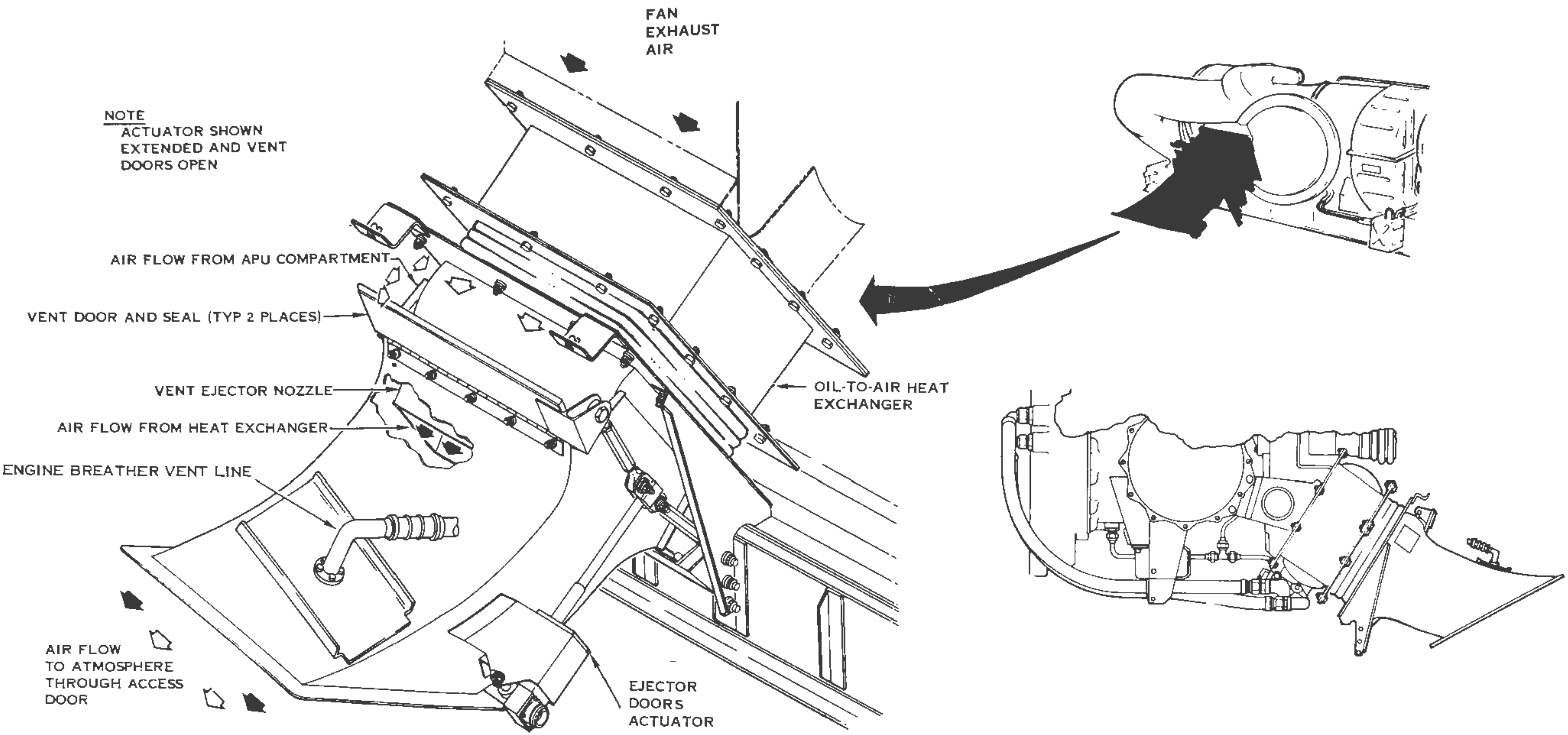
APU COMPARTMENT VENTILATION
FIGURE 5-2

Vent Air Exhaust Valve Description and Operation

The vent air exhaust valve (LCC supplied see Figure 5-2) is a flange mounted, two inch electrically actuated butterfly shutoff valve. A valve position indication lever on the actuator provides visual indication of valve position. Flow direction arrows are cast into each side of the valve body.

Under all normal conditions, the APU vent air exhaust valve is open to vent compartment air to atmosphere. If the APU automatic fire shutdown circuit is activated, or if either APU fire shutdown handle is actuated, the valve closes. The valve opens when these circuits are returned to normal.

Until the valve is closed the APU automatic fire extinguisher is not operative. When the valve closes, and the closed limit switch actuates, the automatic fire extinguisher circuit through the valve is completed, and the VENT CLOSED light on the Flight Engineer/Second Officer's APU CONTROL panel comes on. The position of the valve has no effect on the operation of the manual fire extinguishing circuits.



VENT EJECTOR SYSTEM
FIGURE 5-3

Vent Ejector Assembly Description and Operation

The vent ejector (Figure 5-3) consists of a rectangular duct with a converging inlet nozzle, two inlet doors, a linear actuator, and a door to actuator linkage. The ejector provides increased ventilation exhaust airflow when the APU is operating. The vent ejector uses oil-to-air heat exchanger discharge airflow to induce scavenge airflow from the compartment.

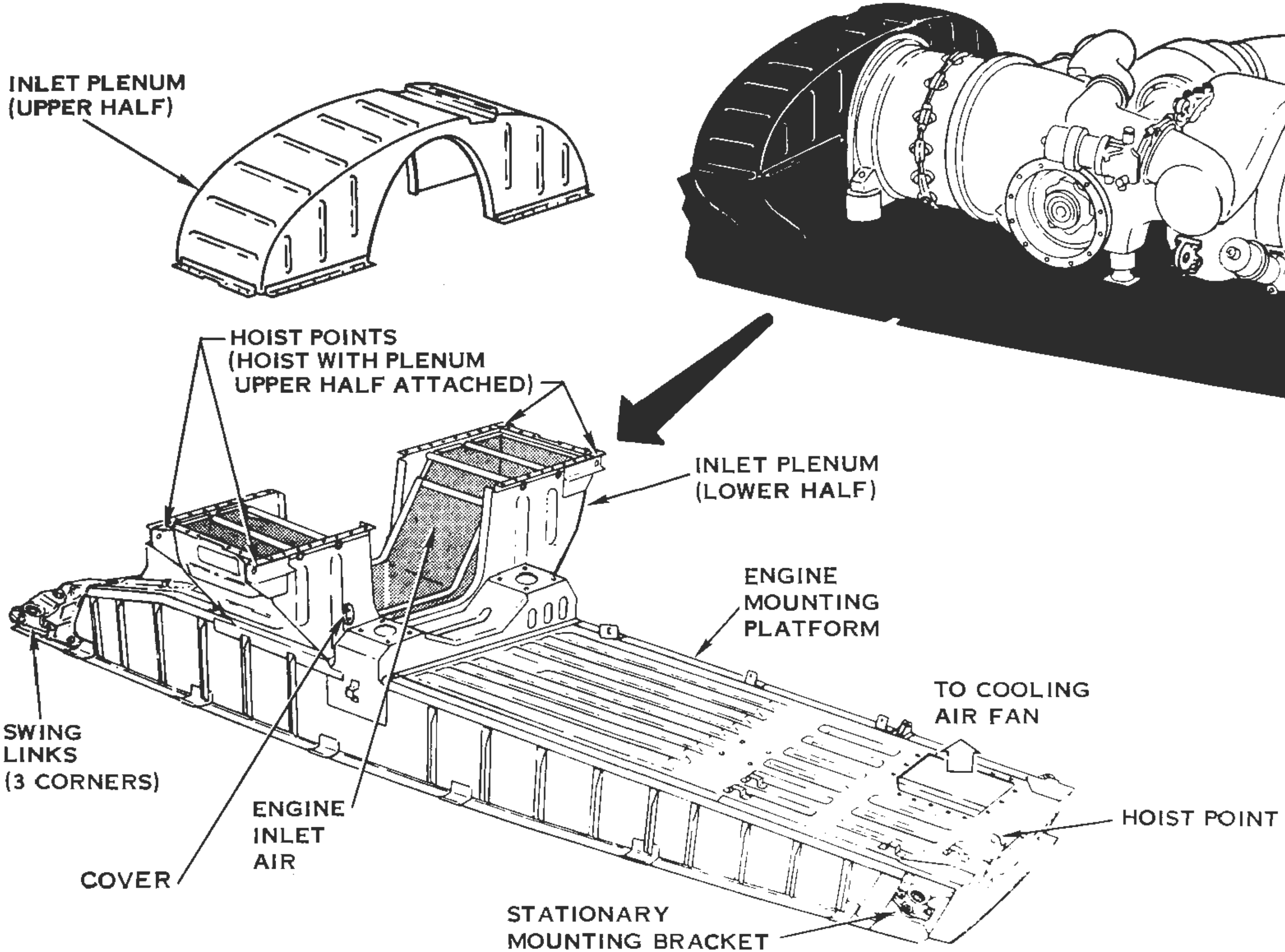
The ejector mounts near the aft right corner of the APU platform. A flexible boot connects the inlet of the ejector nozzle to the oil-to-air heat exchanger discharge flange. The discharge end of the ejector mates with an opening in the aft right APU access door. The small end of the converging inlet nozzle attaches to the rectangular duct leaving narrow gaps on each side (between the duct and the nozzle) to form jet pump inlets. The ejector doors cover the gaps when the APU is not running.

The vent ejector actuator is an eye-mounted jackscrew having a 28 V dc motor with a brake, clutch, reduction gear train, screw-and-nut jackshaft, and two position limit switches. The motor brake releases when either the extend or retract motor fields are energized. The clutch protects the motor and gear train from overloads. The extend and retract limit switches deenergize the motor fields at the travel limits and provide position indication. The actuator mounts on the forward face of the ejector exhaust duct. A bolt attaches the actuator body eye in an inverted U-shaped bracket on the duct. The dual clevis and linkage to the ejector doors support the jack shaft end of the actuator.

The vent ejector is closed except when the APU is in operation. The ejector is controlled by the APU door control relay, simultaneously with the engine air inlet door. The door control relay energizes at the beginning of the APU start cycle, and remains energized as long as the APU is operating. When the door control relay is energized, the doors start to open. When either actuator moves from the closed position, the DOORS IN TRANSIT light on the Flight Engineer/Second Officer's APU CONTROL panel comes on. When both actuators have reached the open position, the DOORS IN TRANSIT light goes off.

When the vent ejector doors are open, exhaust airflow from the compartment is induced as soon as the APU cooling fan starts to provide oil-to-air heat exchanger airflow. The cooling fan is mechanically driven by the APU free turbine and operates continuously as long as the APU is running.

The door control relay is deenergized upon shutdown after a time delay to allow engine coastdown. When the relay is deenergized, the doors start to close. As soon as either actuator moves from the open position, the DOORS IN TRANSIT light comes on. When both actuators have reached the closed position, the DOORS IN TRANSIT light goes off.

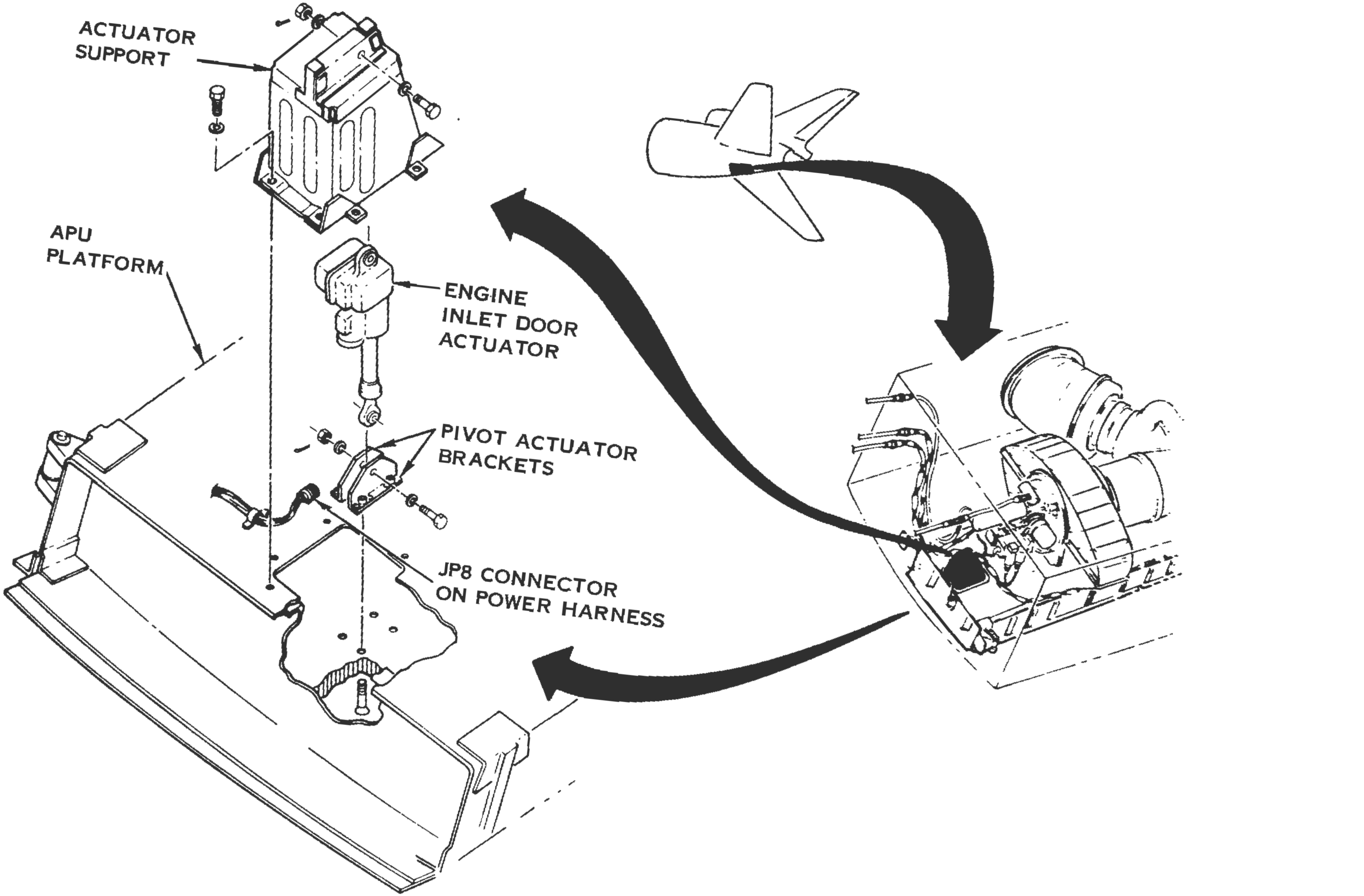


PLATFORM AND PLENUM
FIGURE 5-4

Platform and Plenum Description and Operation

The APU platform and plenum (Figure 5-4) is a rectangular, box-shaped structure upon which the APU engine and components are mounted. The structural strength required to support the APU engine and components is provided by bulkheads, stiffeners, and supports located within the platform. Platform support links (three swing links, one stationary link) on the corners of the platform attach to corresponding points at the aircraft APU compartment structure. This method of attachment permits slight shifting of the APU due to temperature changes. The platform bottom skin is aluminum alloy contoured to form part of the exterior of the aircraft tail section underbody.

The air inlet door located on the platform's lower surface attached to the platform by hinges, is reinforced to withstand normal operating pressures as well as the negative pressure induced by air emergency door closing while the APU engine is still turning. When opened the door provides the passageway for outside air to enter the platform. The air is then ducted thru internal passageways in the platform to the APU engine inlet air plenum and inlet air duct to the cooling air fan. The lower half of the engine inlet air plenum mounts on the upper surface of the platform. When the upper plenum half is attached to the lower plenum, the plenum encloses the engine air inlet. The plenum chamber slows inlet air flow and reduces the air turbulence at the engine inlet.

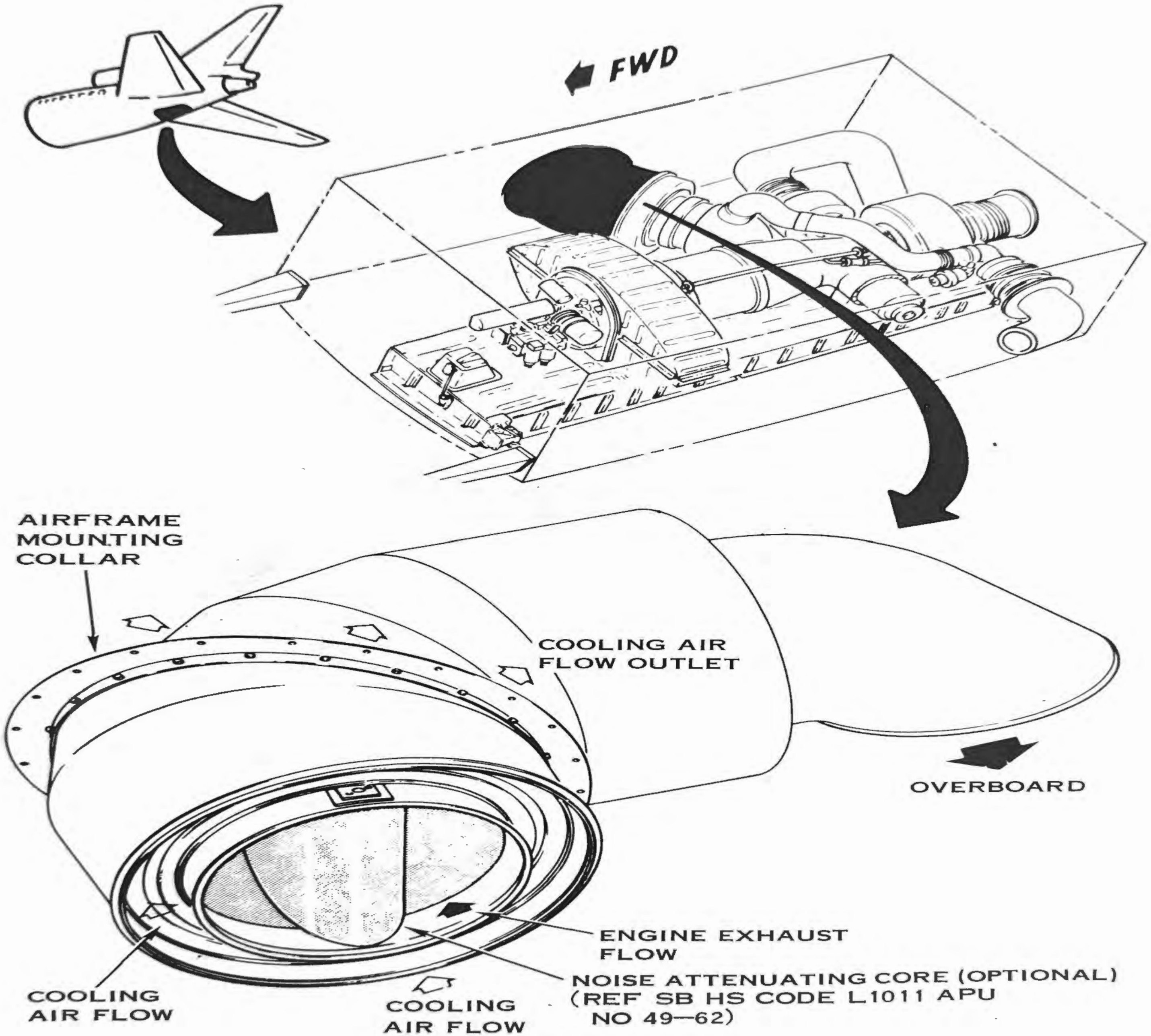


ENGINE INLET DOOR ACTUATOR
FIGURE 5-5

Engine Inlet Door Actuator Description and Operation

The engine inlet door actuator (Figure 5-5) is an electrical motor-driven unit consisting of a dc motor with an integral magnetic brake and a gear train with manual override and position switches. The actuator mounts within a housing on the forward end of the platform connecting the housing to the inlet door.

The actuator in response to a 28 V dc electrical power signal, or activation of the manual override, provides linear motion to drive the APU engine inlet door to the full open or full closed position. The door is normally closed unless an engine start is initiated. At the initiation of a start cycle, as the door leaves the closed position, a switch closes to latch the actuating relay and also supply a signal to the DOORS IN TRANSIT light on the APU CONTROL panel. The START button may then be released and the start cycle will continue automatically. As the door opens beyond 45%, a switch closes to complete a circuit thru the APU Electronic Controller which enables starter operation. At the full open door position another switch closes to remove power from the "drive open" motor windings to turn off the DOORS IN TRANSIT light and to energize the aircraft power control relay that applies 28 Vdc to the APU Electronic Controller initiating APU startup. If the door were to move toward closed more than 45% while the APU is running, the 45% open switch would open a circuit within the APU Electronic Controller which immediately shuts down the engine to prevent damage. At shutdown, the inlet door full closed position disables the master power reset relay and power control relay latch.



APU EXHAUST MUFFLER
FIGURE 5-6

Exhaust Muffler Description and Operation

The APU exhaust muffler (Figure 5-6) consists of two concentric ducts which attach to the APU engine exhaust duct. The outer duct has a collar which attaches to the APU compartment wall. The inner duct has a flattened sound attenuating core. Honeycombed stainless steel covers a noise-deadening facing over the inner core and inner duct walls.

All parts of the exhaust system are constructed of high temperature corrosion resistant steel. A diffuser bolted to the engine exhaust flange protrudes into the sound attenuation chamber or "muffler". The diffuser is divided into two sections connected by means of a coupling accessible within the APU compartment. A flexible sleeve containing two braided metal seals connects the diffuser duct to the muffler and allows freedom of movement between these parts caused by thermal expansion and movements of the APU on its shock mounts.

The muffler ends in a necked down section which extends to the skin of the fuselage. A short extension (supplied by LCC) attaches to the muffler to direct hot exhaust gases just beyond the muffler outlet. The muffler portion of the exhaust system normally remains in the fuselage when the APU is removed.

The APU exhaust muffler attenuates engine exhaust noise, as it conducts engine exhaust gases to the aircraft exterior. Cooling air from the load compressor cooling fan flows through the annulus between ducts reducing the temperature of the inner duct, outer duct and shroud.

APU TROUBLESHOOTING

APU TROUBLESHOOTING

GENERAL

This APU troubleshooting section is designed to aid in defining a problem and provides suggested means of correcting the problem. As such, it is supplemental to the information contained in the (Lockheed) Maintenance Manual.

In addition to the schematic provided in the APU troubleshooting section, detailed electrical system schematics are provided under APU CONTROL SYSTEM and should be used as required. Individual component electrical schematics are also provided in the applicable section throughout the handbook where these components are covered in detail.

The troubleshooting information contained herein does not limit itself to the APU hardware supplied by Hamilton Standard but extends itself to the L-1011 aircraft wiring and related interfaces.

NOTE: Prior to attempting to troubleshoot the APU system, the PREREQUISITES described in the Lockheed Maintenance Manual 49-11-00 and local airline maintenance safety procedures should be followed.

APU and APU Electronic Control System Circuits: Power Off Continuity Check (Refer to APU Electronic Controller Schematic Diagram Figure 6-1 and APU Electronic Controller Interface, Figure 6-2).

NOTE: Figure 6-2 is intended as a troubleshooting convenience, showing the APU Electronic Controller interface relationship.

1. Preparation for Power Off Continuity Test:

   (a) Verify that MASTER POWER switch on flight station APU CONTROL panel is set to OFF (Reference Figure 4-2).

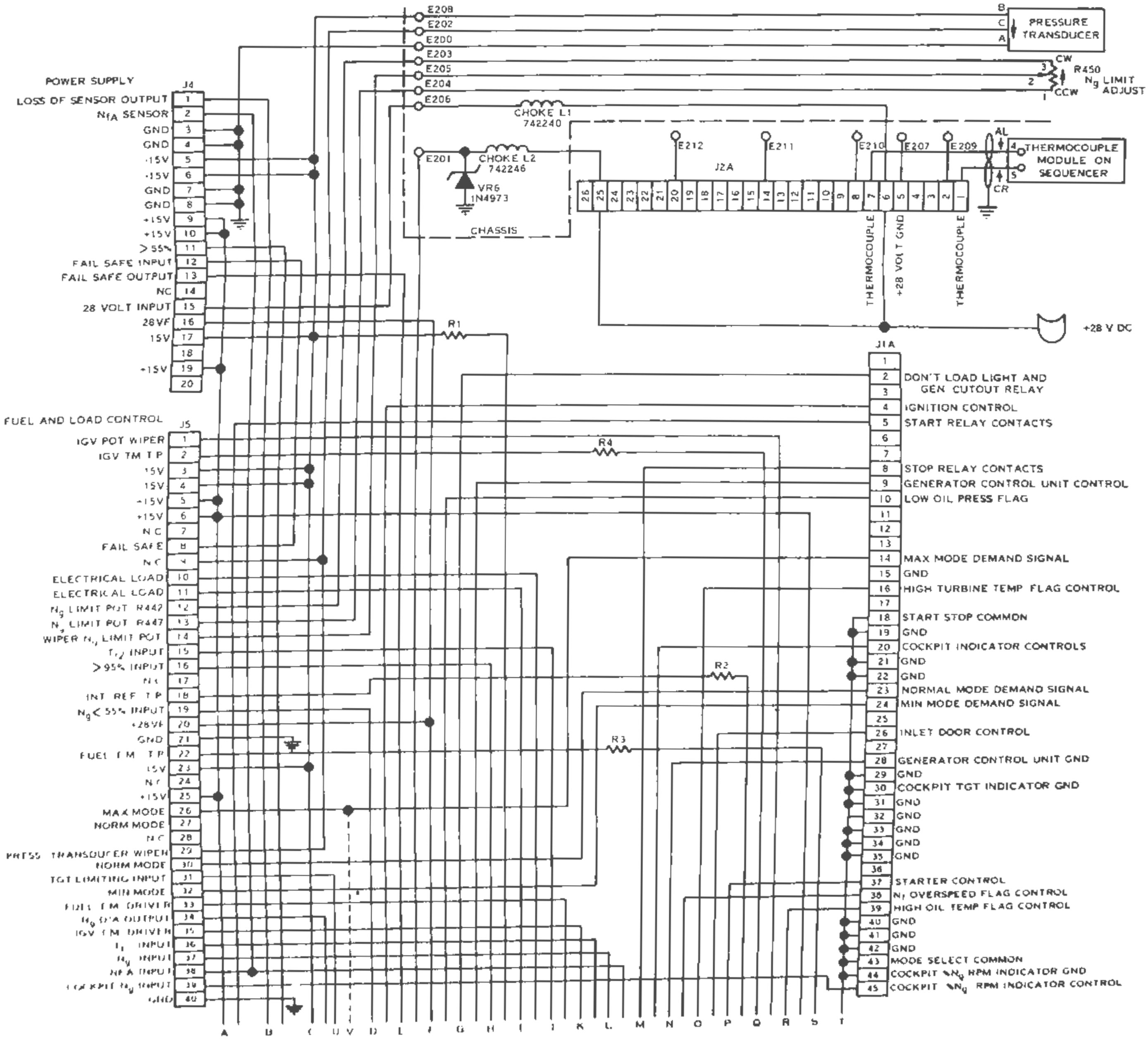
   (b) Remove APU Electronic Controller from rack (AESC Reference Figure 4-4 sheet 1 of 2).

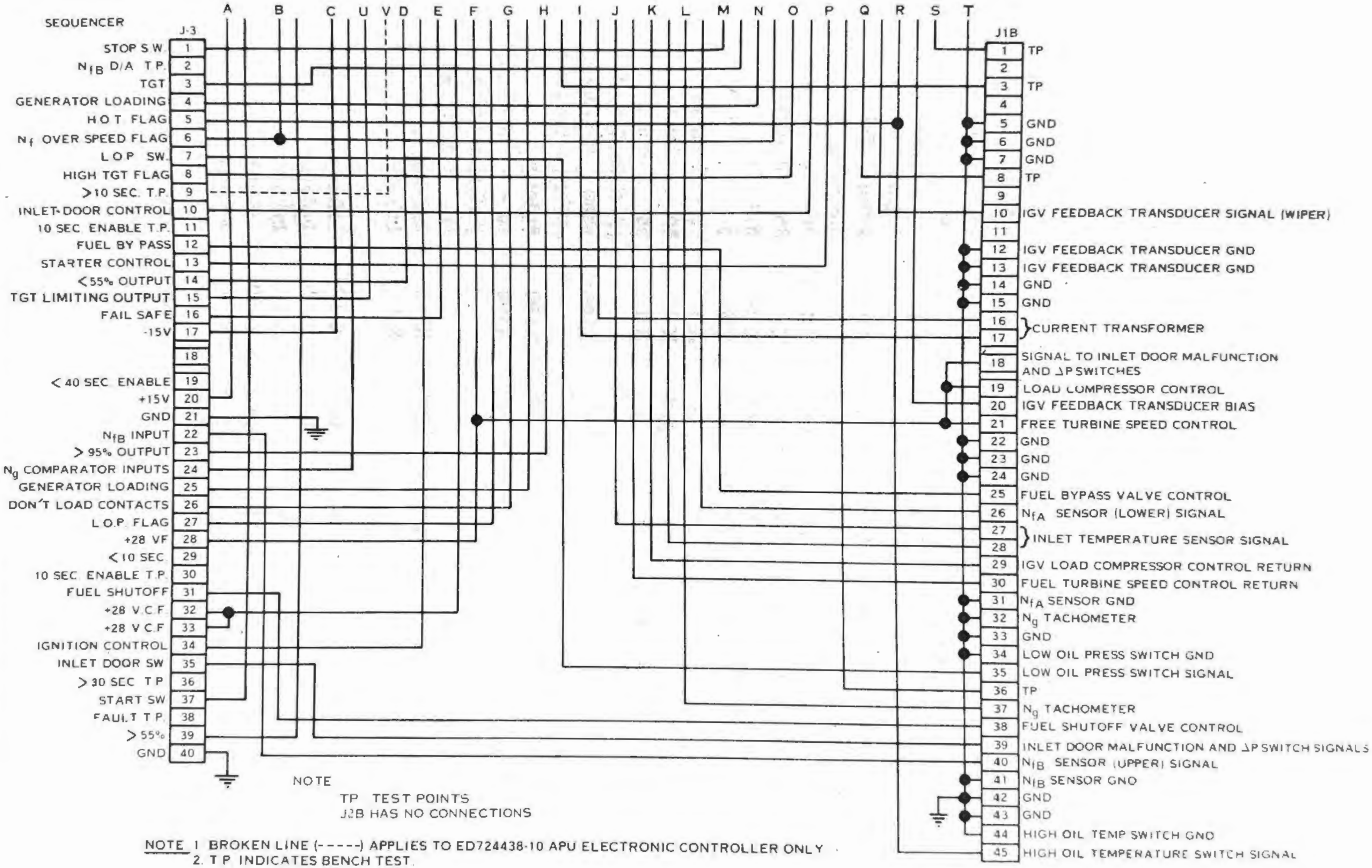
   (c) Continuity test the APU Electronic Controller "rack connectors" using a Simpson 260 meter or equivalent.

NOTE: Set meter polarity switch so that red test lead has negative battery polarity. Most ohmmeters are constructed in this manner but check to be sure.

2. APU Electronic Controller connector J1B mates with outboard bottom rac aircraft connector J6B.

APU ELECTRONIC CONTROLLER SCHEMATIC DIAGRAM
FIGURE 6-1. (SHEET 1 OF 2)





NOTE 1. BROKEN LINE (-----) APPLIES TO ED724438-10 APU ELECTRONIC CONTROLLER ONLY.
2. T.P. INDICATES BENCH TEST.

APU ELECTRONIC CONTROLLER SCHEMATIC DIAGRAM
FIGURE 6-1. (SHEET 2 OF 2)

FUNCTION	METER BLACK TO PIN	LEAD RED TO PIN	METER SCALE	RESULT
IGV Feedback Transducer	10	20	X100	11.0 K ± 1 K ohm
	12	20	X100	11.0 K ± 1 K ohm
	12	13	X 1	Less than 1/2 ohm
	10	13	X100	499 (1.5 to 2.5 K ohms)
	10	grd	X100	Infinity
	10	42	X100	Infinity
	grd	42	X 1	Less than 1/2 ohm
Current Transformer	16	17	X 1	8 ± 2 ohms
	16	grd	X 1	Infinity
Engine Inlet Door 50% Sw. in series with ΔP Switch	18	39	X 1	Infinity (Inlet door closed)
	18	grd	X 1	Infinity
Load Compressor Controller	19	29	X 1	36 ± 10 ohms
(IGV Torque Motor)	19	grd	X100	Infinity
Free Turbine Speed Controller	21	grd	X100	Infinity
(Fuel Torque Motor)	21	30	X 1	62 ± 10 ohms
Fuel Bypass Sol.	25	grd	X 1	30 ± 5 ohms
N_{fA} Free Turbine Speed Sensor	26	31	X 1	20 ± 5 ohms (P/N 738703-2)
			X100	1700 ± 300 ohms (P/N 738703-1)
	26	grd	X100	Infinity
Inlet Temp Sensor (T_t Transducer)	27	28	X100	10 K ± 2 K ohms (8.5 K at 75°F, 12.0 K at 32°F)
	27	grd	X100	Infinity
Low Oil Press Sw.	34	35	X 1	Infinity
	34	grd	X100	Infinity
	35	grd	X100	Infinity
High Oil Temp.	45	44	X 1	Infinity
	44	grd	X100	Infinity
Gas Generator Tachometer (N_g)	32	grd	X100	Infinity
	32	37	X100	420 ± 100 ohms

FUNCTION	METER BLACK TO PIN	LEAD RED TO PIN	METER SCALE	RESULT
N_{fB} Free Turbine Speed Sensor	40	grd	X100	Infinity
	40	41	X 1	20 ± 5 ohms (P/N 738703-2)
			X100	1700 ± 300 ohms (P/N 738703-1)
Fuel S/O Sol.	38	grd	X 1	30 ± 5 ohms

3. APU Electronic Controller connector J1A mates with outboard top rack aircraft connector J6A.

DONT LOAD	2	grd	X 1	200 ± 50 ohms
START/STOP	5	grd	X100	Infinity
	5	18	X100	Infinity
	8	18	X 1	Less than 1/2 ohm
	18	grd	X100	Infinity
GCU (on speed signal)	9	28	X100	6000 or more ohms
	9	grd	X100	6000 or more ohms
	28	grd	X 1	Less than 1/2 ohm
TGT Indicator	20	30	X100	200 ± 50 ohms
	20	grd	X100	Infinity
% N_g RPM Ind.	44	45	X 1	Infinity
	44	grd	X100	Infinity
Door Control Grd.	26	grd	X100	Infinity
Ignition Control	4	grd	X100	260 ± 50 ohms
Mode Select (NORM, aircraft	23	grd	X100	Infinity
S/N 1091 and earlier) (MIN, aircraft S/N 1092 and later)	23	43	X100	Less than 1/2 ohm
(NORM)	24	grd	X100	Infinity
	24	43	X100	Infinity (in NORM or MAX)
(MAX)	14	grd	X100	Infinity
	14	43	X100	Infinity (in NORM or MAX)
(common)	43	grd		Infinity

FUNCTION	METER BLACK TO PIN	LEAD RED TO PIN	METER SCALE	RESULT
Shld. Grd.	42	grd	X1	Less than 1/2 ohm
Starter Relay	37	grd	X1	60 + 10 ohms

4. APU Electronic Controller connector, J2A mates with inboard top rack aircraft connector, J5A.

Shld, Grd.	2	grd	X1	Less than 1/2 ohm
TGT	1	7	X1	20 + 5 ohm
	1	grd	X100	Infinity
	7	grd	X100	Infinity
Ground	5	grd	X1	Less than 1/2 ohm
Continuous 28V dc	6	grd	X100	Infinity
	6	25	X1	Less than 1/2 ohm
Ground	8	grd	X1	Less than 1/2 ohm
Ground	14	grd	X1	Less than 1/2 ohm
Ground	20	grd	X1	Less than 1/2 ohm

APU and APU Electronic Control System Circuits: Power Application Check

1. Preparation
   (a) External electrical power on A/C.
   (b) Remove APU Electronic Controller from rack (AESC).
   (c) Jumper APU Electronic Controller rack connector J6A pin 26 to ground.

2. On the FE/SO APU CONTROL panel, place the MASTER POWER switch to ON, then release switch	• Switch solenoid must hold switch ON • PRI light (APU PRI S/O valve) must illuminate briefly as valve opens • AUTO FIRE shutdown light must illuminate ARMED • DONT START light may illuminate (for aircraft having APU boost pump only)
3. Disconnect APU oil float switch (JP5) (R.H. front of APU near ignitor control box) and jumper pins 1 to 2 of connector	• LOW OIL QTY light must illuminate
4. Remove jumper in oil float switch connector - reconnect to switch	• LOW OIL QTY. light must extinguish
5. Disconnect APU fuel filter (delta P) switch (JP3) (R.H. front of APU forward of Oil Float) and jumper pins 1 and 2 of connector	• FUEL FILTER light must illuminate
6. Remove jumper in fuel filter switch connector - reconnect to switch	• FUEL FILTER light must extinguish
7. Disconnect APU oil temperature switch (JS5) (L.H. forward side of APU near oil filter) and jumper pins 1 to 2	• Check APU Electronic Controller rack connector J6B pins 44 to 45 for less than 1/2 ohm resistance
8. Remove jumper in oil temperature switch connector - reconnect to temperature switch	• Resistance from pins 44 to 45 of J6B must increase to infinity

9. Press START button and hold for two seconds, then release	• DOOR IN TRANSIT light must illuminate for approximately 10 seconds, then extinguish • APU inlet and vent ejector doors must open • AC Generator adapter PRESS light must illuminate when DOOR IN TRANSIT light goes out
10. Test for nominal 28V dc to ground at APU Electronic Controller pack connector J5A pins 6 and 25	• Voltage must be present at both pins
11. Press and release START button while checking APU Electronic Controller connector J6A pins 5 to 18 for continuity and 8 to 18 for open	• Resistance must be less than 1/2 ohm from pins 5 to 18 • Resistance must read infinity on highest scale of ohmmeter from pins 8 to 18
12. Press and release STOP button, while checking APU Electronic Controller connector J6A pins 8 to 18 for continuity and 5 to 18 for open	• Resistance must be less than 1/2 ohm from pins 8 to 18 • Resistance must read infinity on highest scale of ohmmeter from pins 5 to 18
13. Press TGT Indicator BITE Switch	• Indicator must read 1100°C
14. Press % Ng RPM Indicator BITE Switch	• Indicator must read 100% N_g RPM
15. Jumper APU Electronic Controller connector J6A pin 10 to ground	• LOW OIL PRESS fault flag must drop (no others should drop)
16. Remove jumper and press fault flag RESET button on APU CONTROL panel	• LOP flag must reset
17. Jumper APU Electronic Controller connector J6A pin 16 to ground	• OVERTEMP TGT flag must drop (no others should drop)
18. Remove jumper and press fault flag RESET on APU CONTROL panel	• TGT flag must reset
19. Jumper APU Electronic Controller connector J6A pin 38 to ground	• OVERSPEED N_f flag must drop (no others should drop)

20. Remove jumper and press fault flag RESET on APU CONTROL panel	• N_f flag must reset
21. Jumper APU Electronic Controller J6A pin 39 to ground	• HI TEMP OIL flag must drop (no others should drop)
22. Remove jumper and press fault flag RESET on APU CONTROL panel	• HI TEMP OIL flag must reset
23. Press FE/SO's panel light test switch	• All APU fault flags must drop and pilot's annun. APU/eng. status lights must flash • APU Electronic Controller connector J6A pins 10, 16, 38 and 39 must show no continuity to ground with ohmmeter positive battery lead on each pin

NOTE: Most ohmmeters are made with black test lead giving + polarity of internal battery. Check meter to be sure, as this is a check of blocking diodes.

24. Release FE/SO's test switch and press flag reset	• All flags must reset
25. Check the continuity across APU Electronic Controller rack connector J6B pins 18 to 39	• Resistance must be 1/2 ohm or less. (Door open)

NOTE: Remove APU ignitor connector (JP6) (R.H. forward side of APU top side of silver box) and prepare to measure voltage across pins 1 and 2 of connector

26. Jumper APU Electronic Controller connector J5A pin 25 to J6A pin 4	• Ignition relay must actuate and apply 28V dc to pins A and B of ignitor connector JP6

NOTE: Remove jumpers but leave connector disconnected for next step.

27. Momentarily (for 2 or 3 seconds) jumper APU Electronic Controller connector J5A pin 25 to J6A pin 37	• Starter relay must actuate and APU will begin to crank

NOTE: Do not crank APU for more than a few (2 or 3) seconds.

28. Measure for 28V dc to ground at T/R Power Control relay pin A3	• 28V dc must be present
29. Jumper APU Electronic Controller connector J5A pin 25 to J6A pin 2	• DONT LOAD light must illuminate. Voltage must no longer appear at pin A3 of T/R Power Control relay

NOTE: For Aircraft through S/N 1037, Generator Cutout relay must energize and remove 28V dc from pin B3.

30. Remove jumper	• DONT LOAD light must extinguish. Voltage must again appear at pin A3 of T/R Power Cont. relay and B3 of Generator Cut-out relay (A/C prior to S/N 1038 only).
31. Press BLEED AIR S/O switchlight and latch IN	• Initial temperature of APU Bleed Air S/O valve solenoid must feel cool to touch
32. Rotate mode select switch to MIN. MODE	• Check for less than 1/2 ohm resistance between APU Electronic Controller connector J6A pins 24 and 43
33. Rotate mode select switch to NORM	• APU Electronic Controller connector J6A pins 24 to 43 must lose continuity and pins 23 to 43 must show less than 1/2 ohm resistance
34. Rotate mode select switch to MAX MODE	• MAX MODE light must illuminate, APU Electronic Controller connector J6A pins 23 to 43 must lose continuity and pins 14 to 43 must show less than 1/2 ohm resistance
35. Feel Bleed Air SOV Solenoid	• Solenoid must feel warm to touch

36. Unlatch BLEED AIR S/O switchlight

- APU Electronic Controller connector J6A pins 14 to 43 must lose continuity and pins 24 to 43 must again show less than 1/2 ohm resistance

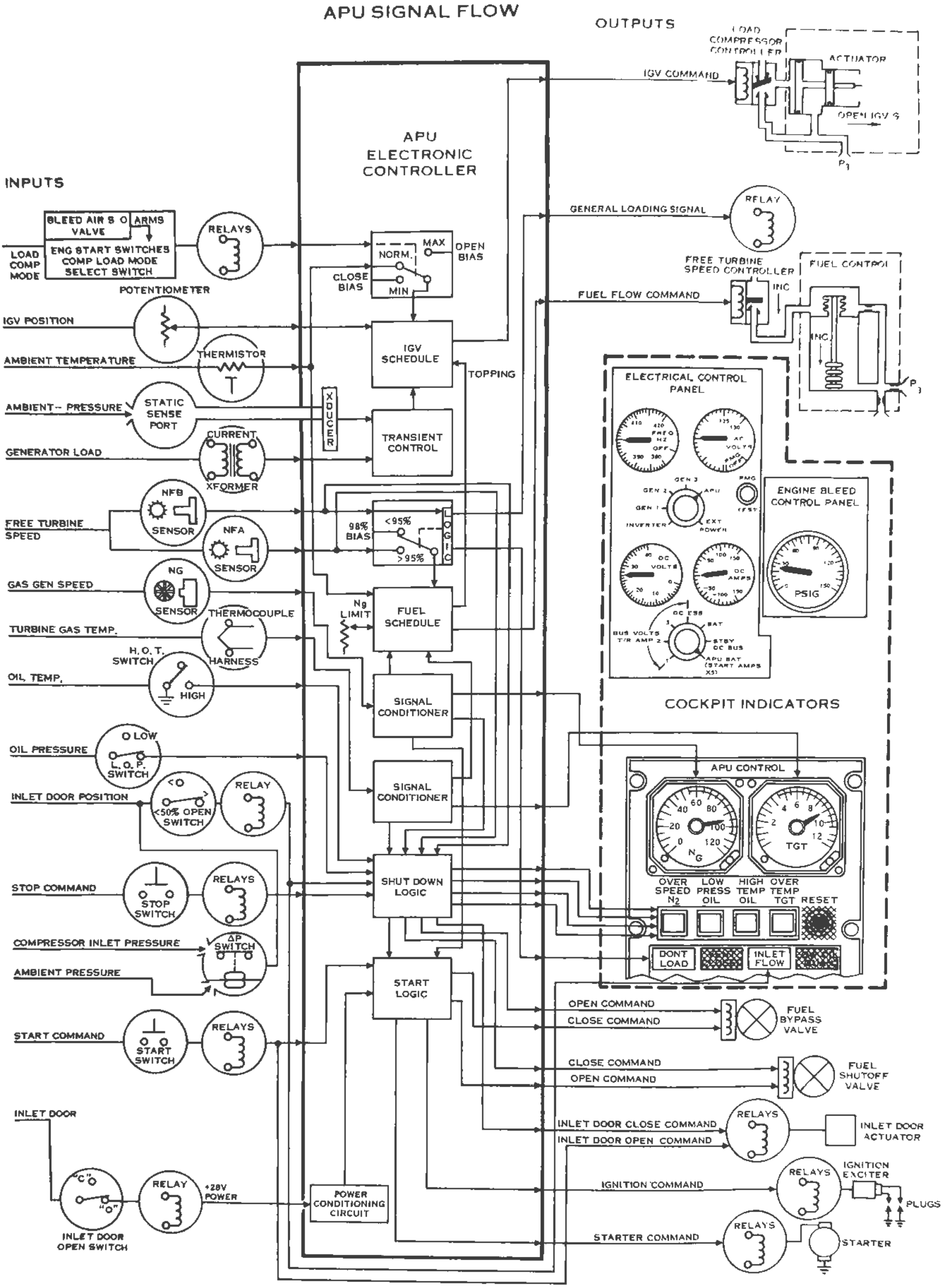
NOTE: Again latch the BLEED AIR S/O switchlight

37. Remove APU Electronic Controller connector J6A pin 26, jumper to ground

- DOORS IN TRANSIT light must illuminate for approximately 10 seconds, then go out
- GEN PRESS light must remain ON
- Engine inlet and vent ejector doors must close
- Bleed Air SOV solenoid must cool

38. Leave MASTER POWER switch ON long enough to verify bleed air SOV solenoid is cooling as a result of Step 37

NOTE: Turn MASTER POWER switch to OFF and replace APU Electronic Controller in rack and secure it. Replace APU connectors removed for tests.



APU ELECTRONIC CONTROLLER INTERFACE

FIGURE 6-2

Report Problems and Probable Causes/Corrective Action

NOTE: Refer to the two previous subsections for proper electrical values when performing troubleshooting per this section.

Report Problem	Probable Causes/Corrective Action
1. APU MASTER POWER switch in APU CONTROL panel will not latch ON.	1. Check APU power control (CB-S13) battery power circuit (CB3-B10) breakers (Flight Engineer/Second Officer's aft C/B panel) and make sure that they are closed.
	• Check power control RCCB (5 amp RCCB, lower left corner of APU relay panel AESC) to see that it is ON. If not, manually engage.
	• Hold MASTER POWER switch on while watching Battery Power RCCB button in MESC Battery Power Control Box. The ON flag must be visible. If not, manually engage to see if panel lights illuminate; if they do, replace RCCB. If not, check wiring through external APU CONTROL panel POWER ON switch-light.

Reported Problem	Probable Causes/Corrective Action
2. APU will not start - engine inlet door remains closed.	2. Check APU Electronic Controller firmly seated in rack (AESC). • Verify inlet door RCCB has ON flag visible. • Check for loose or broken wires at TB828 Modules 21, 22, 23, 24 & 26 or at TB834 Modules 12, 13 & 21 (AESC). • Check Start relay, Stop relay and Engine Inlet Door relays. • Check actuator.
3. APU will not start (engine does not crank) - inlet door open, APU generator pressure light does not come on, and DONT LOAD light does not come on. NOTE: There are test points located on the APU EQUIPMENT AND POWER CONTROL PANEL (AESC) adjacent to the Voltage Regulator. Test point F permits a check of 28V dc to the switch from A/C wiring and test point G permits a check of 28V dc from the actuator open limit switch to Master Power Reset relay and Power Control relay (AESC).	3. Check for APU engine inlet door actuator limit switch malfunction - If bad replace actuator. • If 28V dc present at both test points, check Power Control relay. If not energized, replace it. If energized, check for 28V dc at terminals B2 and B1. • Check for loose wires in module block above APU fire bottle area (9811 TB1081 2Y & 3Y). • Check APU Electronic Controller is firmly seated in rack (AESC). If okay, replace APU Electronic Controller.

Reported Problem	Probable Causes/Corrective Action
4. APU will not start (no Ng indication) - Engine inlet door opens, APU ac generator pressure light on.	4.A. Monitor battery ammeter for current draw and if there is none:

NOTE: The APU starter motor duty cycle is limited to no more than three consecutive APU engine start or start attempts of 30 seconds duration (with a 30 second OFF period between starts). This should be followed by a minimum of one (1) hour cooling off period.

- Check for voltage at starter during 50 second period following START button push. If okay replace starter.
- Check for operation of starter relay in Battery Power Control box (MESC) during 50 second period following START button push. If okay, check for open current limiter.
- Check for voltage (28V dc) at X_1 of starter relay during 50 second period following START button push. If voltage present replace Starter relay.
- Test contact X_1 of starter relay for no short to ground. If short to ground, repair.
- Remove APU Electronic Controller (AESC) and check for continuity between J6B connector pins 18 and 39. If an open condition exists check jumper pins A and B of the APU Load Compressor delta P switch. If continuity now okay replace switch assembly.

Reported Problem	Probable Causes/Corrective Action
	4.A. (Cont'd)
	If open condition still present replace inlet door actuator.
	• Check for continuity between J2A-6 and J1B-18, J1B-19 and J1B-21 (plus probe on J2A-6) should be less than 1000 ohms (reverse polarity should be approximately 2000 ohms). If open, check IGV torque motor (J6B-19), fuel torque motor (J6B-21) and door malfunction switch (J6B-18) to ground. Recheck appropriate (load compressor control, free turbine speed control or inlet door actuator) component. Replace shorted part or repair wiring problems before replacing APU Electronic Controller.

Reported Problem	Probable Causes/Correction Action
	4.B. Battery ammeter indicates current draw during start attempt but no Ng indication. • Remove coil assembly from Ng Tachometer and inspect rotor and/or coil for damage. • Remove Starter and inspect drive coupling for damage and freedom of armature to rotate. • Using a suitable tool rotate starter gearbox drive to see that it turns freely. If drive is seized, replace APU. • Remove APU Electronic Controller from rack (AESC) and check for 420 ± 100 ohms between pins 32 and 37 of rack connector J6B and for infinite ohms between pin 32 and airframe ground. If not okay, replace gas generator tachometer.
5. APU will not start - engine hangs at approximately 18% Ng. NOTE: The APU starter motor duty cycle is limited to no more than three consecutive APU engine start or start attempts of 30 seconds duration (with a 30 second OFF period between starts). This should be followed by a minimum of one(1) hour cooling off period.	5. During start attempt select a fuel tank boost pump on in each of the tanks supplying fuel to the APU. If APU then starts the pumps should be continued in use as the tank(s) fuel level(s) are insufficient to provide a positive fuel feed to the APU.

Reported Problem	Probable Causes/Corrective Action
	5. (Cont'd)

- With the APU Master Power Switch on make a visual check of position indicators on the primary and secondary fuel shut-off valves (should be forward) to see that they are both open.

- Remove both APU engine ignitors and inspect for wear. If the ignitors are in good condition and are wet (indicating fuel available), motor the engine and listen for ignitor snap. If there is none heard, check to see that ignition RCCB (upper right hand corner of APU EQUIPMENT AND POWER CONTROL PANEL AESC) has ON flag visible - if not, manually set.

- Check for 28V dc at APU engine ignition exciter input while engine motoring above 10% Ng and if 28V dc present, check ignitor leads.

- Check to see that APU Electronic Controller and controller rack connector pins are not pushed back and that the APU Electronic Controller is properly seated in the rack (AESC).

Reported Problem	Probable Causes/Corrective Action
	5. (Cont'd) • Check for wiring problem in ignition relay circuit. If ignition appears normal and ignitors are not wet with fuel, check the fuel system. • Disconnect fuel line to manifold at the fuel control unit and using a suitable container (Approximately 1/2 gallon to collect fuel) motor the engine by pressing the START button. With the engine motoring about 10% Ng, the fuel should be coming from the out port. • If fuel flows from the fuel control unit out port, reconnect the line. Remove the drain fitting from the drip tank and motor the engine: If fuel runs from drain as engine is being motored, the problem is a sticking flow divider/ dump valve - replace the valve.

Reported Problem	Probable Causes/Corrective Action
	5. (Cont'd)

- If fuel does not flow from the fuel control unit out port, make a voltage check at the connectors of the fuel shut-off and bypass solenoids with the engine motoring above 10% Ng. 15 to 28V dc should be present at pin 1 of both connectors. If voltage is not present verify APU Electronic Controller firmly seated in rack (AESC) ; then check wiring from the APU Electtronic Controller and if wiring checks o.k - replace the APU Electronic Controller.

- If voltage is present, check for a normal ground at pin 2 in either connector and if a problem exists correct as necessary.

- If the above appears normal check P1 fuel pump discharge pressure at test port in fuel control. (For this check, use tank boost pumps to insure proper fuel supply to APU.) (Ref. Master Key page 1-16, figure 1-9).

Reported Problem	Probable Causes/Corrective Action
	5. (Cont'd) With engine motoring at 18% Ng the pressure should be 80-100 PSIG. If it is not, replace the fuel pump.
6. On start-up, APU engine hangs at approximately 48% Ng and shuts down after approximately 50 seconds.	6. Check for leakage of engine supplied P_3 air between engine and fuel control. Leakage of this magnitude at the engine fitting is usually evidenced by soot accumlation adjacent to the fitting. • Disconnect the pneumatic line between the fuel control unit and free turbine speed controller. With the engine in the hung start condition, very slowly restrict the airflow coming from the fuel control unit. CAUTION: TOO RAPID OR COMPLETE BLOCKAGE OF THE AIRFLOW MAY RESULT SUDDEN ACCELERATION OF THE ENGINE INTO AN OVERSPEED CONDITION. If the engine accelerates replace the free turbine speed controller. If the engine does not accelerate replace the fuel control unit.

Reported Problem	Probable Causes/Corrective Action
7. On start-up, APU accelerates into an overspeed shutdown. (Should this condition occur only during first start attempt after APU cold soaked in-flight, problem most likely in engine fuel control unit. Replace fuel control unit.)	7. Remove APU Electronic Controller. Check for condition at J6B rack connector pins 40 and 41. Check for shorts at pins 40 and 41. If an open condition or a short exists, correct the problem. If an open condition or short does not exist, replace the NfB sensor. NOTE: An improperly adjusted NfB sensor can result in sensor signal loss to controller. • Disconnect pneumatic line between fuel control and free turbine speed controller and, if on start-up, APU still overspeeds, replace fuel control. If APU does not overspeed, replace free turbine speed controller.
8. APU Ng hangs at approximately 83% Ng.	8. Problem most likely in APU inlet temperature sensor circuit. Check aircraft wiring between APU Electronic Controller and temperature sensor for an open condition. Check inlet temperature sensor for proper resistance value. Replace sensor if resistance value shows a high or open condition.

Reported Problem	Probable Causes/Corrective Action
9. N_f overspeed shutdown occurs when Ng reaches approximately 55%	9. During start attempt monitor APU generator PMG (essential buss T/R power must be available to aircraft in order to get PMG, permanent magnet generator, indication). If there is no PMG indication the free turbine is probably seized and the APU should be replaced. If there is APU generator PMG indication check wiring to and through N_{fA} sensor (bottom free turbine speed sensor) for proper condition.
10. On start-up, APU shuts down when Ng reaches approximately 90%, (Refer to problem 11).	10. During start cycle, 90% Ng is the approximate point at which the APU N_f speed will be adequate for normal generator operation and the DON'T LOAD light will go out signaling that T/R (transformer rectifier) power may be substituted in place of the battery to operate the APU. The transfer normally occurs automatically and should the APU shutdown at this point it is probably due to T/R power not getting to the APU circuits. The most likely cause is the T/R Power Control relay located in the AESC (4961-K14 relay).

Reported Problem	Probable Causes/Corrective Action
	10. (Cont'd) NOTE: This applies to A/C serial numbers 1002 through 1037 only. • Check diode module TB828-43 on APU EQUIPMENT AND POWER CONTROL PANEL (AESC) for open condition.
11. APU shuts down when A/C electrical system senses a power interruption e.g., transfer from APU generator power to ground service power or the reverse.	11. Check diode modules TB828-43 and TB828-39 on APU EQUIPMENT AND POWER CONTROL PANEL (AESC) for open or shorted diodes. Check modules for loose or broken wires. • Check T/R Power Interrupt relay (4961-K15) ter- terminals at APU EQUIPMENT AND POWER CONTROL PANEL (AESC) for loose or broken wires. Also check TB828 modules 12, 27, 28, 31 and 42 for loose or broken wires. If there is no wiring problem, replace T/R power interrupt relay (4961-K15).
12. APU N_f overspeed shutdown occurs when pneumatic load is reduced. Shutdown takes place when turning of packs or when main engine start valve closes (may be accompanied by large APU generator frequency and duct pressure fluctuations).	12. Problem suggests a load compressor surge problem. Corrective steps should be taken immediately to identify possible problem and take necessary corrective action.

Reported Problem	Probable Causes/Corrective Action
	12. (Con't)

- A surge rate check should be made. The check requires two people, one at the flight engineer's panel and the other outside the A/C at a point on the left side just forward and outboard of the horizontal stabilizer. Select two air conditioning packs to ON and the APU to NORMAL mode. Select both packs to OFF simultaneously, if a popping sound is heard at the load compressor inlet, discontinue the check and do not use the APU beyond this point as there is a problem in the load compressor inlet or APU surge system. When the APU is replaced, a thorough check should be made of the load compressor inlet duct with a particular emphasis being placed on inspection of the lower end straightening vanes all the way to the leading edges for possible detachment and/or missing pieces. Provided there was was no load compressor surge noticed in the NORMAL mode check, then make the check again this time with the APU selected to MAX mode.

Reported Problem	Probable Causes/Corrective Action
	12. (Cont'd) If after the above checks there was no notice of a load compressor surge, the APU duct check valve should be removed and inspected for possible damage.
13. On start-up, LOP shutdown at 70% to 90% Ng (approximately 10 seconds after reaching 55% Ng).	13. Check oil pressure and oil quantity. If not okay, correct. • Check that the LOP switch is connected. • Check A/C wiring. • Replace LOP switch.
14. Low duct pressure during main engine starting.	14. With condition set for MAX mode operation, check for presence of MAX MODE light and if light is not on, check the A/C IGV MAX Mode Select relay (AESC). • Check A/C wiring between MAX Mode Select relay and APU Electronic Controller. 14B. If low pressure complaint cannot be confirmed there is a possibility that more air conditioning packs were operating during engine starting than should have been. To check for this possibility switch on the no. 2 and no. 3 pack hot air valve and hot air isolation valve switchlights

Reported Problem	Probable Causes/Corrective Action
	14B. (Con't) (pack does not have to be in operation). Place the battery switch to ON and drop all other sources of electrical power to the A/C. Observe the no. 2 and no. 3 pack flow control valve circuit breakers on the pilots overhead panel for approximately 20 seconds (circuit breakers H4 and H5). If either Circuit breaker trips there is a problem in the A/C wiring and it should be corrected as the possibility exists for inadvertent pack operation. Reference Lockheed wiring manual and Lockheed Service Bulletin 093-21-039. 14C. During main engine start (MAX mode), duct pressure between 19-23 psig. NOTE: Start condition can be simulated by 2 packs on and trim air OFF. ● TGT at approximately 1050°C. which suggests TGT limiting and possible hot section distress. Replace APU.

Reported Problem	Probable Cause/Corrective Action
	14C. (Cont'd) • Possible load topping due to excessive electrical load. Reduce the electrical load to below 50 kw. No additional action needed. • Ng limit adjust on APU Electronic Controller improperly set. Adjust. • APU engine compressor dirty and in need of a wash. Perform compressor wash. 14D. When in MAX mode (no more than 2 packs operating) duct pressure is below 19 psig. • Surge valve not closing. Check operation by selecting three packs ON. Observe surge valve actuator arm with APU in MIN mode. Arm should be full forward for correct operation. • Possible load compressor damage. Inspect load compressor and replace APU if damage found.

Reported Problem	Probable Cause/Corrective Action
	14D. (Cont'd)

- Inspect APU load compressor housing and ducting downstream of APU for a rupture.

14E. When selecting to MAX mode, APU Ng, TGT and duct pressure do not increase.

- With the APU shutdown, apply approximately 12 psig air pressure to IGV actuator supply line (use test fitting for surge valve or apply air directly to line at outlet from surge valve). Observe the IGV's fully open.

- If guide vanes do not open fully, block off vent at load compressor controller. If guide vanes then open, replace the load compressor controller.

- If guide vanes do not open, apply air pressure directly to actuator. If guide vanes open check to see that seal was installed on servo tube between the load compressor controller and actuator at controller end. If guide

Reported Problem	Probable Cause/Corrective Action
	14E. (Cont'd) vanes still do not open replace APU.
15. APU operating parameter fluctuations (Ng, TGT, generator frequency and duct pressure). Can hear pulsing at APU exhaust.	15A. Duct pressure fluctuations in excess of 3 psig and generator frequency in excess of 2 Hz. • Observe actuator arm on surge valve and if valve cycling occurs, then problem may be in surge control or surge valve. Replace APU.
	15B. Ng and TGT fluctuations with only slight duct pressure and generator frequency fluctuations. • If condition is present in all modes, then check Ng tachometer for possible damage. If okay replace fuel control unit. • If condition is present in MIN and NORM modes but stable in MAX mode, then replace free turbine speed controller (torque motor).

Reported Problem	Probable Cause/Corrective Action
16. APU operates in MAX mode at all times. CAUTION: OPERATING IN MAX MODE PRODUCES HIGHER THAN DESIRED ENGINE OPERATING TEMPERATURES. EXCESSIVE MAX MODE OPERATION WILL UNNECESSARILY SHORTEN ENGINE HOT SECTION LIFE.	16. Short to ground in wiring from MAX mode select relay to APU Electronic Controller. MAX mode select relay or engine ground start relay malfunction. • Check that APU Electronic Controller is firmly seated in rack (AESC). • Check connection to load compressor controller. • Check for broken wires from APU Electronic Controller to load compressor controller. • Check load compressor inlet guide vanes and IGV actuator for binding. • Replace the load compressor controller. • Replace the APU Electronic Controller.
17. TGT indication erratic or lower than normal.	17. Check wiring between T_1, T_3, T_7 temperature sensing harness and APU Electronic Controller for proper resistance through harness. Repair or replace as necessary.

Reported Problem	Probable Cause/Correlation Action
	17. (Cont'd) • Check wiring between APU Electronic Controller and TGT Indicator. • Check that APU Electronic Controller is firmly seated in rack (AESC).
18. APU shuts down with TGT flag when MAX mode is commanded.	18. Wash APU engine compressor. • T_1, T_3, T_7 temperature harness generating high (erroneous)signal. Check harness for proper resistance. • Observe TGT with APU operating in MAX mode and two air conditioning packs in operation. If the TGT is 1010°C or greater and the above two actions did not identify a problem, there is hot section distress and/or engine inlet blockage. Replace APU.
19. Fuel leaking from fuel control unit vents and/or fuel control unit to pump parting surface.	19. Problem may be fuel pump drive seal. Replace fuel control unit and fuel pump.

Reported Problem	Probable Cause/Corrective Action
20. During APU start-up, TGT shutdown occurs (may be accompanied by exhaust torching).	20. APU engine compressor stalls may be caused by engine bleed valve being stuck closed or caused by engine inlet blockage. Replace APU.